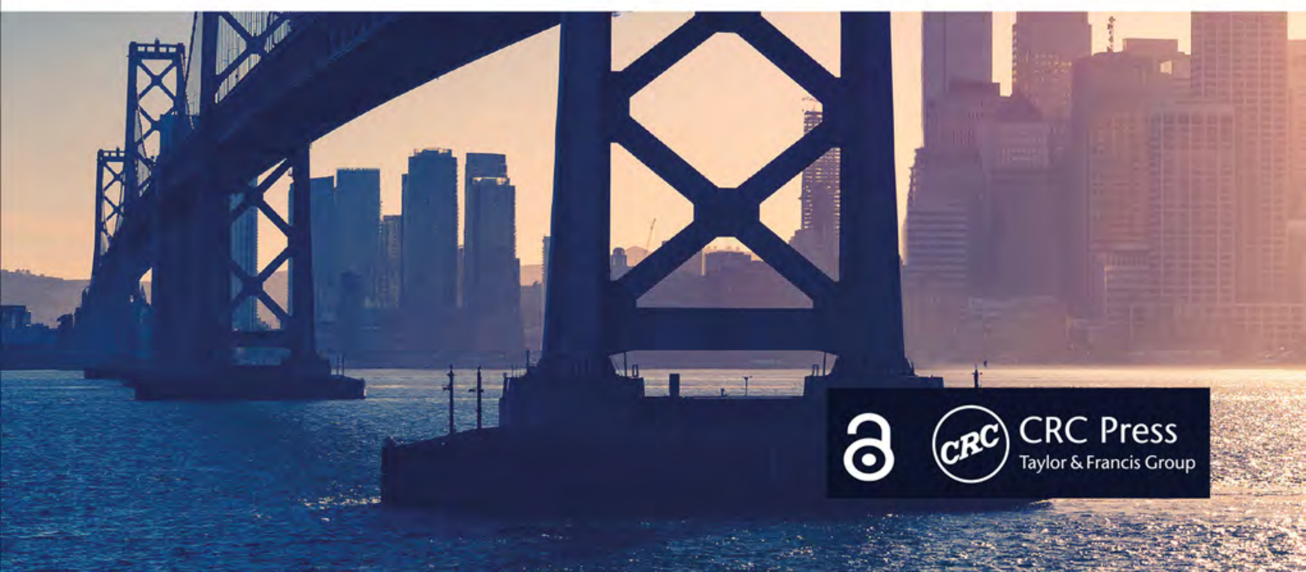
DEVELOPMENT AND INFRASTRUCTURE IN DEVELOPING COUNTRIES: A 10–YEAR REFLECTION

Edited by
Innocent Musonda, Erastus Mwanaumo, Adetayo Onososen
and Retsepile Kalaoane



DEVELOPMENT AND INVESTMENT IN INFRASTRUCTURE IN DEVELOPING COUNTRIES: A 10-YEAR REFLECTION

Development and Investment in Infrastructure in Developing Countries: A 10-Year Reflection includes the contributions to the 10th International Conference on Development and Investment in Infrastructure (DII-2024, Livingstone, Zambia, 24–26 July 2024). The papers discuss, evaluate and devise ways of maximising the benefits of infrastructure development and achieve outputs that will inform policy and wider development goals. This Open Access book is invaluable to leaders, researchers, practitioners, and stakeholders involved or interested in infrastructure development in developing countries.

PROCEEDINGS OF THE 10TH INTERNATIONAL CONFERENCE ON DEVELOPMENT AND INVESTMENT IN INFRASTRUCTURE (DII-2024), 24–26 JULY 2024, LIVINGSTONE, ZAMBIA

Development and Investment in Infrastructure in Developing Countries: A 10-Year Reflection

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Theme 10: Digital innovation in construction & digital transitioning

Theme 11: Land, project management & capacity development

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Preface

On behalf of the Organizing Committee, I welcome you to the International Conference on Development and Investment in Infrastructure (DII-2024). The DII-2024 conference is part of the DII Conference series on Infrastructure Development and Investment in Africa. It aims to provide an international forum for leaders, researchers, practitioners and other stakeholders in infrastructure development to discuss and dev ways of maximizing benefits from infrastructure development in Africa and achieve outputs that will inform policy.

The 2024 conference, themed "*Development and Investment in Infrastructure in Developing Countries: a 10–year reflection*" will address a broad range of topics around infrastructure to evaluate and draw lessons on innovations, empowerment, growth and sustainable development.

The broad topics covered by the conference include:

1. Sustainability in Infrastructure Development
2. Infrastructure Investment - Trends and Forecasts
3. Smart Infrastructure and Cities
4. Quality and Resilient Infrastructure
5. Gender Equity, Empowerment, and Development
6. BIM, Digital Twins, Mixed Reality, 3D Printing and Construction Innovation
7. Climate Change, Shock Events Impact, Response and Water Resources
8. Environmental and Waste Management
9. Investment and Finance
10. Renewable Energy
11. Construction Cost management
12. Construction Materials
13. Lean Construction and Value Engineering
14. Construction Ergonomics, Health, and Safety
15. Social Justice and Social Inequality in Construction
16. Circular Economy in Construction

Warm gratitude is extended to the authors who have successfully gone through a two-tier peer-review process to have their papers accepted and published in this proceeding. The peer-review process would have been impossible without the support of the Scientific and Technical Review Committees (STC) members. The organizing committee is thankful for this voluntary service central to the quality of the accepted papers.

Special thank you also goes to all the conference delegates from different continents. Thank you for attending the event.

Innocent Musonda
For/DII-2024

Acknowledgements

The Organising Committee of the DII-2024 is grateful to the Development Bank of South Africa (DBSA), CYPE Software, and Calliper Consulting Engineers for sponsoring the conference. Their support was invaluable to the massive success of the conference.

We appreciate the University of Zambia, Copperbelt University, Zambia, National Council for Construction (NCC), Zambia, University of Johannesburg, South Africa, and other African and international universities and institutions for supporting the conference through their valued contributions.

The contributions and exceptional support of the international advisory and scientific committees, who worked tirelessly to prepare refereed and edited papers to produce these published proceedings to satisfy the criteria for subsidy by the South African Department of Higher Education and Training (DHET), is truly treasured.

We are grateful to all the keynote speakers, panellists, authors, poster presenters, the organizing and scientific committees, reviewers, and session chairs for contributing to the success of DII-2024. Their invaluable contribution helped us achieve insightful discussions at the conference.

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Declaration

All the papers in these conference proceedings were double-blind peer-reviewed at the abstract and full paper stage by the members of the International Review Committee. The process entailed a detailed review of the abstracts and full papers, reporting comments to authors, modification of articles by authors whose papers were not rejected, and re-evaluation of the revised articles to ensure the quality of content.

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Scientific and Technical Review Committee

This committee ensured that the final papers incorporated the reviewers' comments, were correctly allocated to the appropriate theme and met the requirements set by the organisers in line with international standards for inclusion in the proceedings. They also arranged the papers into their final sequence, as the table of contents captured. The committee ensured that the papers were of the highest standard regarding the originality of material, academic rigour, contribution to knowledge, critical current literature review, research methodology and robustness of findings, empirical research findings, and overall quality and suitability for inclusion in the conference proceedings.

Editorial Board

Scientific Reviewers

The panel of scientific reviewers comprised experts from the built environment who ensured the originality of material, academic rigour, contribution to knowledge, critical current literature review, research methodology and robustness of findings, empirical research findings, and overall quality and suitability for inclusion in the conference proceedings

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The Peer-Review Process

The need for high-quality conference proceedings, evident in the accepted and published papers, entailed a rigorous two-stage blind peer review process by no less than two acknowledged experts in the subject area. Experts, including industry professionals and academics, were assigned to ensure that high standards of scientific papers were produced and included in the proceedings.

The first stage of the review
Submitted abstracts were twice blind reviewed. Each abstract was examined to ensure relevance to the conference theme and objectives, academic rigour, contribution to knowledge, originality of material and research methodology. Authors whose abstracts were accepted were provided with anonymous reviewers' comments and requested to develop and submit their full papers considering the abstract review comments.

The second stage of the review
Reviewers were assigned the submitted full papers according to their expert. The full papers were reviewed to ensure relevance to the conference theme and objectives, originality of material, academic rigour, contribution to knowledge, critical literature review, research methodology, robustness of analysis of findings, empirical research findings, overall quality and suitability for inclusion in the conference proceedings.

Third stage review
Authors whose papers were accepted after the second review were provided with additional anonymous reviewers' comments on evaluation forms and requested to submit their revised full papers. Evidence was required relative to specific actions taken by the authors regarding the referees' suggestions. After satisfactory evidence was provided, final papers were only accepted and included in the proceedings.

To be eligible for inclusion, these papers were required to receive a unanimous endorsement by all the reviewers that the paper had met all the conditions for publication. Of 107 submissions, 68 papers were finally accepted and included in the DII-2024 conference proceedings. The review process was managed on the Oxford abstract system.

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

Regards,
Innocent Musonda
Chair: Scientific Programme

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Peer Review Process (PRP) Confirmation

On behalf of the DII-2024 International Conference on Infrastructure Development and Investment Strategies for Africa, I confirm that the manuscripts accepted for oral presentation and publication in the Conference proceedings were blind peer-reviewed by two (2) or more technical specialists.

The reviewers were selected from the experts in the Scientific and Technical Review Committee. To be eligible for inclusion, the papers, reviewed through a three-stage review process (abstract, full paper and final paper), received unanimous endorsement by all the reviewers that they had met all the conditions for publication. All accepted manuscripts will be published via the conference proceedings.

Regards,
Dr Neema Kavishe
Leeds Becket University

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Keynote Address Abstracts

Mr Chuene Ramphele
Keynote Topic: Infrastructure Development in Developing Countries: Reflections on building better
Abstract: Challenges that developing countries experience with regard to development and investment in infrastructure continue to be complex, intricate and fast-paced. The ability of developing countries' institutions to deliver infrastructure is lacking behind and incongruent by far. Simply put, the infrastructure needs in developing countries far surpass the capacity of fiscus exacerbated by negative economic growth across many. For example, the economic development in the South African Development Communities (SADC) has for the past 10 years achieved annual average GDP growth of around 2.0% and the funds in the region have to achieve the scale and impact needed to enable sufficient cross-border integration that indicates economies of scale. Foreign Direct Investment flows into SADC have averaged 2.2% (US$16 bn) of the GDP over the last 10 years but landed below the historic average at only 1.5% (US$12.5 bn) of GDP in 2022. Consequently, developing countries tend to be forced to exercise a balancing act, which is often difficult, on regional and domestic priorities. Development and investment in infrastructure are critical for economic growth and building prosperity. However, the infrastructure financing gap is increasingly widening each year with African Development Bank estimating between $130 billion and $170 billion annually required for infrastructure development leaving a gap of $100 billion. It has become sacrosanct for developing countries to focus on leveraging regional integration to build resilient economies. Innovation in development, financing, execution and maintenance is key to driving sustainable initiatives focusing on mission-critical infrastructure networks – energy, freight transport, water and digital communication. The past 10 years demonstrated that the future of development and investment in infrastructure depends on intensifying the project preparation and development facilities, Governments increasing fiscus commitments on infrastructure investment to at least 4.5% - 6% of GDP and establishing regional financing mechanisms that will stimulate private sector investments.

Dr Nadine Ibrahim
Keynote Topic: Engineering Education in Sub-Saharan Africa: Developing Talent through Innovation and Collaboration
Abstract: A review of engineering education in Sub-Saharan Africa highlights several key trends that together indicate a path forward for advancing engineering education in Africa, with implications for the higher education sector more broadly. Specifically, the authors take a lens of developing talent through innovation and collaboration. We draw on critical reflections provided by various deans, heads of departments, and faculty members in engineering schools in Africa, and various secondary data sources. First, we underline the necessity

to enhance the quantity and quality of engineering talent in Africa, particularly in the Sub-Saharan Africa (SSA) region, in light of key global trends including rapid urbanisation, climate change and population growth. Second, we explore the disconnect between the supply and demand for African engineering talent and discuss some of the key contributing factors. We derive from this disconnect not only the need for greater investment in higher education but also the need for pedagogical innovations and global collaboration. Third, we highlight new educational opportunities that have arisen due to the culmination of trends toward rapid expansion of internet access in Africa and recent pedagogical innovations that enhance the quality of education using modern information and communication technologies. Fourth, we review some of the innovative approaches and organisations in Africa that are using modern communication technologies to enhance the quality of and access to educational opportunities. Lastly, we call for deeper and more innovative educational collaborations involving institutions both within and outside Africa that capitalise on emerging opportunities emanating from a more interconnected global society.

Engr Bridget Ssamula

Keynote Topic: Smart and Resilient Infrastructure for Emerging Economies: Perspectives on Building Better

Abstract: Infrastructure development is a cornerstone for economic advancement, especially in emerging markets where resilient systems can drive growth and prosperity. This keynote addresses the pivotal role of infrastructure in economic development, emphasizing the necessity of resilience and sustainability in design and implementation to meet evolving demands. In emerging economies, infrastructure is crucial for service delivery across sectors such as education, healthcare, water supply, and transportation. Aligning infrastructure development with the United Nations Sustainable Development Goals (SDGs) ensures inclusive and equitable growth. This keynote explores how smart infrastructure can bridge gaps in service delivery, promoting access to quality education, healthcare, and essential services, thereby uplifting communities and driving sustainable development. The discourse centres on four pillars shaping the engineering response to infrastructure challenges in emerging economies: equity, engineering education, sustainability through the lifecycle, and innovation in design and technology. Equity-focused infrastructure prioritises inclusivity and access for all segments of society, particularly marginalised and underserved communities, driving social cohesion and economic empowerment. A paradigm shift in engineering education is essential, integrating sustainability principles, advanced technologies, and interdisciplinary approaches to equip future engineers with the skills necessary for designing and implementing resilient infrastructure. Sustainability at every stage of infrastructure delivery, from planning and design to construction, operation, and maintenance, minimises environmental impact and ensures long-term viability and resilience against climate change and other disruptions. Leveraging cutting-edge technologies such as IoT, AI, and smart materials creates infrastructure that is adaptive, efficient, and resilient, optimizing resource use, enhancing operational efficiency, and providing real-time data for proactive maintenance and management. By focusing on these pillars, we can create a blueprint for smart and resilient infrastructure that supports the socio-economic development of emerging economies. This keynote presents case studies and best practices from around the world, demonstrating how integrated and sustainable infrastructure can drive progress towards a more equitable and prosperous future. Building better in emerging economies requires a concerted effort to design and implement infrastructure that is resilient, sustainable, inclusive, and equitable. By aligning with global sustainability goals and harnessing innovation, we can pave the way for a brighter and more sustainable future for all.

Ms Suma Stephen Mwaitenda
Keynote Topic: Inclusive Infrastructure: A Tale of an African Woman
Abstract: Inclusive infrastructure is simply development that enhances positive outcomes in social inclusivity and ensures no individual, community, or social group is left behind or prevented from benefiting from improved infrastructure. How then do we come about to have integrated, reliable and affordable transport, water, energy and information & communications infrastructure? At this 10th anniversary of DII, a forum for leaders, researchers, practitioners, and stakeholders in infrastructure development. Over the years we have discussed, evaluated and developed ways of maximising the benefits of infrastructure development and achieved outputs to inform policy and wider development goals. Are we winning? This keynote objectively addresses inclusive infrastructure at three stakeholders' levels, the industry, policy makers and the woman herself. At a time when technology and innovation are booming when the world seems to be as connected as ever, mega infrastructure projects across Africa, capacity building and capacity development initiatives as well as sustainability initiatives. Can we finally tell a tale of triumph? Or hope to live to tell of it?

Mr George Kanyika
Keynote Topic: Infrastructure Development as an Agent of Socio-Economic Transformation in South Africa
Abstract: Infrastructure development in South Africa is pivotal for socio-economic transformation, requiring meticulous planning to ensure successful outcomes. Poorly designed projects can disenfranchise intended beneficiaries, highlighting the need for key enablers focused on applicability and measurability. South Africa has significantly invested in infrastructure to improve citizen livelihoods and address Apartheid-induced imbalances. President Cyril Ramaphosa emphasises infrastructure's role in achieving developmental goals, highlighting its potential to improve lives, provide essential services, expand economic opportunities, create jobs, and boost business competitiveness. Infrastructure development, encompassing tangible assets and intangible systems, shapes the built environment, facilitates activities, and promotes sustainable growth. Successful infrastructure projects require careful planning, efficient implementation, and effective management to achieve socio-economic benefits. Enhanced connectivity, improved productivity, job creation, investment attraction, and social development are key outcomes of robust infrastructure. Policymakers, planners, and stakeholders must address critical success factors to ensure these benefits and improve community quality of life. The "Inkululeko Development Projects" in Ndumo village serves as a case study, demonstrating significant rural transformation through targeted infrastructure investment. Twelve years post-implementation, questions are regarding employment sustainability, investment success without downstream activities, and community alignment with infrastructure goals. These inquiries guide evaluations of infrastructure programs, offering insights for replicating successful models across South Africa, aligned with the District Development Model (DDM).

Arch Mundashi Alex Mwango

Keynote Topic: Developing a Checklist for Sustainable Housing in Zambia

Abstract: Checklists for rating the viability of housing proposals remain an essential tool for any Local Authority to regulate the development of housing settlements within their jurisdiction. They ensure that the prevailing human settlement policy, which informs local building codes, standards or regulations, is incorporated in the design and implementation of housing projects. This paper sets out to advocate for the formulation of a rapid desktop checklist that will incorporate indigenous building practices drawn from informal housing, the 2016 Sustainable Housing Guidelines for Zambia (SHGZ), and the Triple Bottom Line principles of Sustainable Development (SD) to promote sustainable housing in Zambia. It draws on the experience of the speaker working in both the formal and informal housing sectors and argues for policies related to social justice, environmental protection and economic development to be integrated into a checklist that will be used to rate the sustainability of housing proposals by Local Authorities. This should be developed in partnership with private and public stakeholders in the formal and informal housing sector and will replace the old pre-independence standards that are currently used. The fusion of formal and informal practices and the SHGZ objectives will consequently lead to a housing landscape in Zambia that conforms with local SD principles and urban policies. The overarching goal of the checklist is the implementation of affordable and acceptable sustainable housing that has Indigenous practices at its core and is a monumental step in achieving local SD goals.

Engr Wesley Kaluba

Keynote Topic: Zambia's National Road Tolling Programme: Its Sustainability and Benefits

Abstract: The National Road Tolling Programme is a strategic initiative by the Zambian government aimed at enhancing the country's road infrastructure through sustainable financing mechanisms. Since its inception, the programme has significantly contributed to the maintenance and expansion of Zambia's road network. This tolling programme provides a steady stream of revenue for road maintenance and development, reducing the dependency on external funding and government budgets. With dedicated funds, we have seen notable improvements in the quality of our roads, leading to reduced vehicle operating costs and enhanced road safety. The Engineering Institution of Zambia (EIZ) provides technical expertise to ensure that road projects meet the highest engineering standards. Our members are actively involved in the planning, design, and supervision of road construction projects. We invest in the continuous professional development of our engineering professionals, equipping them with the latest skills and knowledge to tackle infrastructure challenges effectively. EIZ engages with policymakers to advocate for sound infrastructure policies and regulations that promote sustainability and innovation in the road sector. As the voice of the profession, EIZ is uniquely positioned to drive collaborations with government, businesses, communities, and experts to upgrade infrastructure and make it climate change resilient.

Editor Biographies

Innocent Musonda holds a PhD in Engineering Management and qualifications in construction management and civil engineering. He is a registered civil engineer (Zambia), construction manager (South Africa), and a full member of the chartered institute of the building (CIOB-UK) and the International Council for research and Innovation in Building and Construction (CIB). He has worked for both the public and private sectors in Southern Africa. He is currently a Professor in Construction Project Management, researcher, invited speaker, founder and director of the Centre for applied research and innovation in the built environment (CARINBE) based at the University of Johannesburg.

Erastus Mwanaumo holds among other certificates a PhD, MSc and BSc specialising in Engineering, Project and Construction Management. He is former Vice President for the African region of the Chartered Institute of Building. He is a Fellow of the Chartered Institute of Building (FCIOB), a registered civil engineer, construction Project manager, Chartered Surveyor with Royal Institute of Chartered Surveyor (MRICS) and member of the Dispute Resolution Board Foundation. Erastus has raised over US$ 7.6 Million of research funds from European Union, Royal British Academy, Royal Academy of Engineering, and African Development Bank as Principal and Co-Principal Investigator. He has coordinated funds for Infrastructure and improving workshops and laboratory equipment in excess of US$4 Million. He has delivered research and professional guest speeches in over 18 countries globally, supervised over 82 Master and 11 PhD Candidates to completion, including examination of 18 PhD theses in his fields of specialisation. Erastus also consult for World bank, European Union, NTU Strategic Development Consultants of Denmark, AECOM and DFID of UK. He is currently serving as one of the Examiner and Patent Reviewer for African Regional Intellectual Property Organization (ARIPO) in technological advancement for economic, social, technological, scientific and industrial development.

Adetayo Onososen holds a PhD in Construction Management and qualifications in Quantity Surveying with interests in researching Sustainable Infrastructure delivery. He is a distinguished interdisciplinary researcher specializing in digital innovations at the nexus of BIM, Digital Twins, drones, robotics, and Extended Reality applications, particularly Virtual Reality, with a strong focus on enhancing learning experiences.

Retsepile Charity Kalaoane holds a PhD in Urban and Regional Planning from the University of Johannesburg, specializing in transportation systems, spatial analysis, urban planning, GIS, and digital transformation. At the Centre for Applied Research and Innovation in the Built Environment (CARINBE), she leads projects on sustainable mobility systems, electric vehicles, and optimizing sustainable urban mobility. Retsepile has pioneered numerous research efforts and led initiatives in urban mobility in MASERU, the urban informal economy and inclusive cities, and sustainable modes of transportation.

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Theme 1: Sustainable infrastructure development

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

A review on the barriers to sustainable energy transitioning in the mining sector

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ABSTRACT: This study explores the shift to sustainable energy in the mining sector, analysing obstacles and strategies for improved sustainable development. It uses a qualitative multi-level perspective (MLP) review of 13 empirical studies from Google Scholar, covering literature from 2012 to 2023. The review highlights the urgent need for the mining sector to adopt sustainable energy sources due to its reliance on fossil fuels and the environmental impacts of renewable sources like hydroelectricity. The study identifies financial, policy, and technical barriers hindering this transition. It advocates a holistic approach involving collaboration between government, mining companies, and stakeholders to overcome these challenges through financial incentives, policy reform, and education on sustainable energy practices. Transitioning to sustainable energy can enhance economic viability, sustainable infrastructure development and environmental sustainability in the mining sector in developing countries like Zambia.

Keywords: Mining Sector, Sustainable Energy Transition, Renewable Energy, Impact, Barriers

1 INTRODUCTION

In the context of global efforts to promote sustainable development, transitioning to low-carbon, renewable energy sources is critical. This shift from traditional, limited or high-carbon energy sources supports social and economic sustainability, minimises environmental impact, and ensures long-term energy security (Rosen and Farsi 2022). A sustainable energy transition involves significant changes in energy behaviours, attitudes, processes, and systems, including the adoption of renewable energy sources and energy-efficient technologies (Blutstein and Rodger 2001; Steg *et al.* 2015). The energy sector, predominantly powered by fossil fuels, accounts for 73% of human-generated greenhouse gas emissions (UN 2021). The mining industry, responsible for substantial energy consumption, contributes significantly to these emissions, consuming 80% of the world's electricity and approximately 1.7% of global final energy consumption (Aramendia *et al.* 2023). Future mineral demand and population

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growth are expected to further increase the industry's energy consumption and CO_2 emissions. To prevent severe climate impacts, global CO_2 emissions must be halved by 2030 (UN 2021). The Paris Climate Agreement calls for urgent action to achieve net-zero emissions by 2050 (Vennapusa *et al.* 2024). International and regional targets, such as the EU's goal to reduce emissions by 80-95% by 2050 and the Sustainable Development Goals, underscore the need for immediate action (Moss *et al.* n.d.; Olabi 2016; Onn and Woodley 2014; UN 2015). The mining industry's increasing energy demands and the need to reduce environmental impacts highlight the importance of sustainable energy transitions. This study aims to identify barriers to the successful implementation of sustainable energy transitioning in the mining sector and emphasise its significance. By exploring these aspects, the study seeks to provide insights that can guide strategies for promoting sustainable energy use in mining operations, aligning industry practices with environmental preservation goals. The following sections review literature on the mining sector and the energy paradox, identify factors for a successful energy transition, describe the study's methodology, present research findings and discussion, and conclude with recommendations and future research directions.

2 THE MINING SECTOR AND ENERGY PARADOX

The mining industry plays a pivotal role in the economies of many countries, particularly in developing nations. For instance, in Zambia, the mining sector significantly influences GDP, employment, and foreign exchange earnings, but it also entails high energy consumption and emissions (ITA 2022). The sector employs approximately 400,000 people formally, accounting for almost 8% of formal employment, with informal employment potentially ranging from 10-30% of the workforce (ILO n.d.; RIA 2020). It generates over 80% of Zambia's export revenues and contributes 8.7-10% to the GDP, with copper alone accounting for over 70% of foreign export earnings (ITA 2022; RIA 2020; World Bank 2020). The mining industry is essential for providing raw materials for manufacturing and other industries, stimulating economic growth, and developing infrastructure and technology in developing countries (AGS n.d.; RIA 2020). However, it is also one of the most energy-intensive industries due to high-energy processes like heating, lighting, pumping, ventilation, excavation, and transportation (Howes 2022; Mining for Zambia 2016).

The sector presents a paradox: while it has a substantial carbon footprint, it is vital for producing materials necessary for sustainable energy solutions, such as copper for clean energy production and cobalt for energy storage. Mining consumes about 38% of global industrial energy use, 15% of global electricity, and 11% of total global energy (Igogo *et al.* 2017). This includes 19% of global coal and coal products, 5% of global gas, and 2% of global oil (Awuah-Offei 2016; Levesque *et al.* 2014). Given its significant energy use, the mining industry must lead the transition towards sustainable energy methods. A focus on energy efficiency and renewables is imperative to reduce emissions and expedite economic development, particularly in developing countries (UN 2021). By addressing this paradox, the industry can balance environmental responsibility with economic success, contributing to sustainable infrastructure development.

3 FACTORS INFLUENCING SUCCESSFUL ENERGY TRANSITIONING

Successful sustainable energy transitioning requires policies, technological shifts, financing, and education (Cossen and Waitz 2016; Kabeyi and Oludolapo 2022; Maennling and Toledano 2018; Sareen and Haarstad 2018). A five-dimensional approach, environment, economy, society, technology, and institutionsis crucial for analysing energy sustainability and guiding resource use (Kabeyi and Oludolapo 2022). Government Policies play a vital role by addressing environmental issues, promoting social equity, fostering economic sustainability, advancing technology, and establishing effective governance (ILO 2019). They can incentivise mines to generate their own energy, reducing dependence on national grids and supporting unmet energy markets (Roux 2002; Soltau 2020). However, policy implementation can be slow, potentially delaying sustainable energy projects in the mining sector (Kabeyi and Oludalapo 2022).

Technological advancements are essential for enhancing sustainability. Smart grids and renewable energy sources like solar and wind are crucial for a sustainable electrical system (Kabeyi and Oludolapo 2022). Technologies must minimise costs and environmental impact while ensuring energy quality and flexibility (Kabeyi and Oludolapo 2022). Solar-powered micro-grids, for example, are feasible for large-scale mining applications, offering scalability and quick installation (BMWi 2016; ILO 2019). Advanced energy storage systems are also needed to manage renewable energy variability (Rehman *et al.* 2010). Furthermore, significant investments in energy infrastructure, efficiency, and renewable energy are required to meet global targets like the Paris Agreement (Bulkot *et al.* 2024; IRENA 2018). Innovative financing mechanisms can address the challenges of capital investment in mines, promoting the adoption of renewable energy and enhancing economic development (Cossen and Waitz 2016; Igogo *et al.* 2017; Maennling and Toledano 2018).

Additionally, education supports sustainable energy transitions by increasing awareness and knowledge about energy conservation (Altassan 2023). It empowers communities, enhances infrastructure literacy, and supports institutional norms (Aron *et al.* 2020). Collaboration among educational institutions, governments, and energy organisations is essential for promoting sustainable practices and developing standardised curricula (Altassan, 2023; Shehad *et al.* 2023). Education also fosters community engagement and stakeholder linkages, driving innovation and effective implementation of sustainability frameworks (Chen *et al.* 2019; Daoudi 2024; Laurence 2011). These factors, policy, technology, financing, and education are interlinked and essential for overcoming barriers to sustainable energy transitioning in the mining sector, particularly in developing countries. They contribute to a holistic approach that balances environmental responsibility with economic and social benefits.

4 METHODOLOGY

This study employed a qualitative multi-level perspective (MLP) that combined a systematic review, scoping study, and thematic analysis to analyse the transition towards sustainable energy in the mining sector comprehensively and minimise bias. The systematic review synthesised current knowledge, directed future investigations, resolved open-ended concerns, and advanced theory development, benefiting legislators, researchers, and decision-makers (Liberati *et al.* 2009; Page *et al.* 2021). The study adhered to the PRISMA 2020 statement for transparent reporting, reflecting updates in terminology and review processes (Page *et al.* 2021). The scoping review, guided by Arksey and O'Malley (2005), aimed to comprehensively locate primary studies and relevant papers. Thematic analysis categorised findings into distinct themes using an inductive approach to identify patterns and trends. Inclusion criteria focused on empirical studies from 2012 to 2023, with no geographical restrictions and English as the preferred language, addressing barriers to sustainable energy transition in mining. Non-empirical studies and irrelevant publications were excluded. The process involved iterative engagement with each stage, including manual searches in Google Scholar and direct Google searches using key phrases like "energy transition," "renewable energy," and "sustainability transition." Data was extracted into an Excel sheet using a checklist based on Swallow and Zulu (2020) and Arksey and O'Malley (2005), covering author name, year, country, study aim, methodology, key findings, and conclusion. Data from 28 sources was standardised and collected. The subsequent items were gathered:

- Author / year / title
- Geographical location
- Aim of the study

- Methodology adopted
- Key findings of the study
- Conclusion of the study

Excel software was used to store and extract the data. Duplicates were carefully reviewed, found, and eliminated by sorting the data alphabetically. Textual data was critically examined, ensuring thorough content analysis of past studies and providing insights for informing the framework design with theoretical and contextual uniqueness. This research primarily relied on secondary data from reliable sources to analyse the transition towards sustainable energy sources and the potential barriers. Through qualitative content analysis, key themes and insights were identified, categorised, and synthesised. The study explored challenges in facilitating the transition to sustainable energy, providing comprehensive insights and implications. A sample of the extraction and review procedure is shown in Table 1.

Table 1. Example of charting data.

No.	Authors	Title	ABSTRACT/ Methodology/ Geography	Publication	Year	Theme
1	Bai, Chunguang; Kusi-Sarpong, Simonov; Sarkis, Joseph;	An implementation path for green information technology systems in the Ghanaian mining industry	Using a multiple case field study with input from managers of the Ghanaian gold mining industry, the adopted GSCM practices framework and methodology is applied. The results provide an evaluation and development path model to guide these organizations and managers for GSCM planning and investment decisions. The path results show that these organizations should first develop SSP (Strategic Supplier Partnership) with their suppliers for implementing GITS (Green Information Technology and Systems) and other GSCM practices. These results provide some exploratory insight and guidelines for managers and policymakers who seek to integrate green initiatives. (Multiple case field study) (Ghana)	Journal of Cleaner Production	2017	Transition + mining

5 RESULTS

Thirteen (13) empirical studies were streamlined provided a comprehensive overview of various authors' philosophies, approaches, strategies, research approaches, data collection methods, data analysis methods, and theoretical lenses used in their respective studies. A multitude of factors influence the shift to sustainable energy in emerging nations. The results of the scoping research review, which found thirteen (13) studies, are summarised in this section. A thematic and content analysis is used to provide the study information, which also includes a brief discussion of the research. The thematic and content analysis provide a practical and theoretically adaptable method of analysis. The thematic analysis approach employed in this study was primarily deductive, using Braun and Clarke's approach for identifying and analysing themes. Through a systematic examination of the empirical studies, themes related to barriers to sustainable energy transition in the mining sector were identified, categorised, and analysed based on existing literature and theoretical frameworks. The predominant themes are influenced by macro-variables encompassing social, political, and cultural factors (Parker 2018). Here are some of the barriers to sustainable energy transition in the mining sector.

5.1 *Lack of leadership*

Leadership is a transformative force in driving the transition towards sustainable practices, as underscored by Hu and Hassink (2016). Their research illuminates how leadership ingeniously constructs institutional niches, such as a renewed cadre incentive and evaluation system, that focus on green development without undermining broader economic and infrastructure frameworks in developing countries. This nuanced understanding of leadership's role contributes significantly to recent advances in comprehending the interactive processes between leadership, institutions, and industrial restructuring at the regional level. Importantly, Hu and Hassink (2016) argue that place leadership doesn't just produce immediate effects on local industrial dynamics but also influences and shapes institutions as 'mediators' of economic practice and interaction, suggesting a profound and enduring impact on sustainable transitions.

5.2 *Need for green education and sensitisation*

The imperative for green education and sensitisation activities is paramount in fostering a collective awareness of the importance and inevitability of transformation and development within mining enterprises, as highlighted by Hou *et al.* (2021). Their emphasis on the government's role in conducting various forms of green education underscores the critical need for proactive initiatives to instil sustainability values and practices. Furthermore, Hu and Hassink's (2016) insight into the leadership's pivotal role extends to the realm of education, where new leaders must not only champion new ideas but also inspire their subordinates to embrace and actively participate in green initiatives. This holistic approach to education and leadership underscores the multifaceted nature of driving sustainable transitions, emphasising the importance of both top-down and bottom-up strategies in fostering a culture of sustainability within mining enterprises.

5.3 *Inadequate energy policy*

Using a decision and management support tool, Bai *et al.* (2017) examined several green management approaches in Ghana. The necessity for cogent policy design was underscored by Hou *et al.* (2021), who highlighted the critical role that government regulations and external oversight play in convincing geological and mining businesses to combine ICT and renewable energy technology. Through a case study in an autocratic, non-Western environment, Hu and Hassink (2017) demonstrated how leadership's response to changes in the macro-context resulted in new institutions and laws in the mining sector. The significance of permissive laws in determining future energy policy is emphasised by this discussion (Parker

2018; Ocelk *et al.* 2021). Carbon pricing mechanisms, renewable energy objectives, and incentives for adopting renewable energy are examples of policy interventions.

5.4 *Lack of stakeholder buy in and participation*

Inclusive governance practices were deemed essential by Ocelk *et al.* (2021), advocating for a shift from technocratic authority-based responses to more inclusive and dialogue-based forms of participation. Elite involvement in investment decisions and policymaking significantly influences patterns of industrial energy consumption (Parker 2018).

5.5 *Technology gaps*

Technology plays a pivotal role in influencing sustainability rhetoric, often intersecting with social, economic, and environmental variables (Parker 2018:15). Bai *et al.* (2017) highlighted the essential role of information technology and systems (ITS) in promoting sustainability in supply chains and organisational operations, as well as in reducing environmental footprints. Hou *et al.* (2021) underscored technological and financial obstacles hindering the mining industry's transition, particularly in integrating renewable energy sources like solar power into sustainable practices. Sustainable mining necessitates green supply chain management (GSCM) strategies, such as strategic supplier partnerships and green IT (Bai *et al.* 2017).

5.6 *High capital cost requirements*

High technological costs were identified as barriers by Nikas *et al.* (2020), highlighting the importance of integrating cost dimensions alongside performance considerations. Hou, Zhu, and Peng (2021) emphasised that technology and cost are the main obstacles hindering the transformation of mining enterprises. The capital-intensive nature of sufficient renewable power generation and energy storage to meet operation energy demands was highlighted by Marsden and Marsden (2021).

5.7 *Lack of reward/penalty*

Hu and Hassink (2016) noted that coercion by local state agencies and state-owned enterprises led to the reallocation of resources from the mining industry. Marsden and Marsden (2021) highlighted the impact of carbon taxes on the mining industry, increasing the cost of transitioning to renewable energy. Nguyen *et al.* (2021) discussed the influence of state growth paradigms on the development of the mining industry in Vietnam, emphasising the need for equitable benefit-sharing systems.

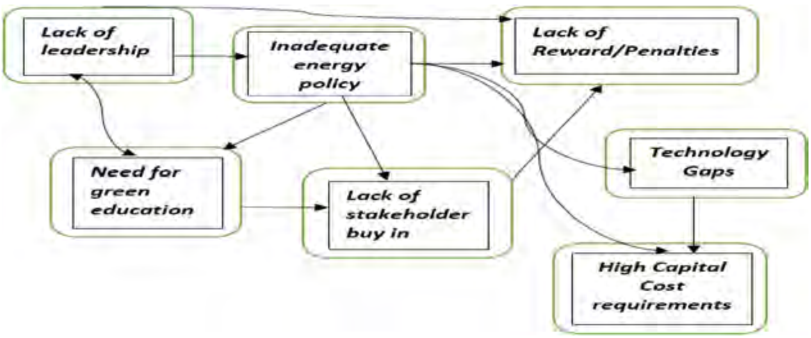

Figure 1. Interaction of the barriers to sustainable energy transitioning in the mining sector.

6 INTERPRETATION AND DISCUSSION

The study identifies several critical barriers and facilitators for sustainable energy transitioning in the mining sector. Inadequate energy policy is a significant barrier, underscoring the need for coherent policy formulation to encourage mining firms to adopt renewable energy technologies (Bai *et al.* 2017; Hou *et al.* 2021). Stakeholder buy-in and participation are crucial for inclusive governance, requiring more dialogue-based forms of participation to mitigate conflict and ensure effective decision-making (Ocelk *et al.* 2021). The importance of technology in facilitating sustainable mining practices is emphasised, with the integration of information technology and systems (ITS) and green supply chain management (GSCM) strategies being essential for promoting sustainability and reducing environmental footprints (Bai *et al.* 2017; Hou *et al.* 2021). Capital cost requirements pose a notable challenge, especially regarding high technological costs, which need to be balanced with performance considerations for a comprehensive evaluation (Marsden and Marsden 2021; Nikas *et al.* 2020). Leadership is identified as a key driver for transition, with the creation of institutional niches focusing on green development crucial for aligning with broader economic and infrastructure frameworks (Hu and Hassink 2016). Reward and penalty mechanisms, such as carbon taxes, play a significant role in incentivising the adoption of renewable energy sources and reducing pollution in the mining industry (Hu and Hassink 2016; Marsden and Marsden 2021). Finally, the need for green education and sensitisation is highlighted as essential for fostering awareness and understanding among mining enterprises about the importance and inevitability of transformation towards sustainable energy practices (Hou *et al.* 2021). These findings underscore the complexity of transitioning to sustainable energy in the mining sector, emphasising the need for holistic approaches that address policy, technological, financial, and social factors to effectively overcome barriers and facilitate the transition towards a more sustainable energy future.

7 LIMITATIONS OF EVIDENCE

A range of studies were identified for the review, potentially impacting the study report. The review included only empirical studies from 2012 to 2023. Although thematic analysis offers flexibility, it can also result in inconsistency and a lack of coherence in developing themes from research data (Holloway and Todres 2003). This flexibility may pose challenges for novice researchers in determining which aspects of the data to prioritise. Conversely, while scoping reviews are broad, they may lack depth.

8 CONCLUSION

The study's in-depth analysis of the mining industry's transition to sustainable energy reveals a complex scene with a variety of themes. A strategic roadmap is established by the staged approach to energy transition, which includes installing power generation, converting equipment, and integrating renewable energy with storage systems. But serious impediments also exist, such as insufficient energy legislation, difficulties in involving stakeholders, financial and technological constraints, and high capital expenses. The role of leadership becomes crucial in creating institutional niches that support green development without undermining larger economic frameworks. The conflict between carbon prices and other incentive and penalty mechanisms complicates industrial responses. Furthermore, programmes for green education become essential for raising consciousness and comprehension. To put it succinctly, the report presents a clear picture of the opportunities and complex obstacles involved in moving the mining industry towards sustainable energy standards. In the quest for a more sustainable and environmentally friendly mining sector, the topics that have been identified offer a strong basis for upcoming studies and policy discussions.

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Rethinking the Corridor of Freedom: Networked transit-oriented development and the polycentric future of the City of Johannesburg

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ABSTRACT: The renowned "Corridor of Freedom" in the City of Johannesburg (CoJ) was originally conceived as a reconciliatory lifeline of post-apartheid planning which acted as an intervention to foster spatial transformation. However, the city continues to encounter lingering inequalities and fractured geography three decades after the ushering in of a democratic dispensation and finds itself at a crossroads of car-centric development and spatial segregation. This study deployed a mixed methods approach, where both qualitative and quantitative data were collected through interviews with relevant stakeholders including CoJ officials and the community. The study findings reveal that the role of networked TOD can promote sustainable mobility and alleviate car independence in the CoJ. Moreover, the paper identifies suitable areas for TOD nodes in the CoJ that are suitable to support networked TOD. The culmination in the development of a Spatial Network and Morphology Framework for Polycentric TOD is named Jozi-Web due to its interconnected and accessibility provision. Such radical rethinking that hinges on Networked Transit-Oriented Development (NTOD) and its potential for an interconnected polycentric urban future promise to encourage sustainable urban development.

Keywords: Networked Transit-Oriented Development, Jozi-Web, Polycentric, Corridors of Freedom, Sustainable Urban Development, Transportation Planning

1 INTRODUCTION

The City of Johannesburg is the vibrant heart of Gauteng and is the economic powerhouse of South Africa. However, the city faces challenges including, an underutilized public transport system, fragmented development, traffic congestion, and private car dependence. To answer these challenges, Kotze and De Vries (2019) envisioned the "Corridor of Freedom" (CoF) as a singular artery of opportunities. The CoF was initially perceived as a linear development approach aimed at bridging spatial divisions and stimulating further economic growth. Nevertheless, Ballard *et al.* (2017) submit that the CoF has valuable infrastructures that are not fully delivering services to their full potential. As many cities' urban fabric develops, they tend to move beyond monocentric development to having multiple centers (Hutton and Paddison 2014). Therefore, a polycentric city spontaneously develops multiple centers that encourage localized economies, enhance accessibility, and diversify communities (Friedmann 2005).

Transit-oriented development (TOD) became known as a promising approach for fostering sustainable urban development by permitting development to mushroom within the constraints of public transport hubs (Domingo and Gumbo 2022). However, the TOD in the City of Johannesburg (CoJ) is equally faced with challenges facing its CoF. According to Simões (2014), TOD revolutionizes the urban landscape within the arena of sustainable urban development by accentuating accessibility, sustainability, and well-integrated transportation systems as the prerequisite for urban and regional planning.

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Consequently, this study challenges the concepts of polycentric traditional monocentric models of cities. Polycentrism envisions cities as multi-nodal and which disperses social, economic, and economic activities across various centres whilst encouraging sustainability, and resilience and enhancing other urban functioning elements. With that being alluded to, this paper advocates for a networked TOD approach where multiple nodes and corridors are strategically interconnected in reshaping the future of CoJ. As networked TOD envisions the city to be polycentric through the interconnectedness of road infrastructure facilitating swift mobility and accessibility, the study names the framework Jozi-web.

2 LITERATURE REVIEW

2.1 *Introduction to networked Transit-Oriented Development (TOD)*

Kapoor and Brar (2022) indicate that the traditional TOD strategies concentrate on a single transportation stop or station which limits their capacity as a singular TOD node. With limited existing literature on networked transit-oriented development, Domingo *et al.* (2024) indicate that TOD is a promising concept in the arena of urban planning. This is because it stimulates liveable and sustainable cities by focusing on development that is planned around mushrooming public transport nodes (Brokl 2022).

Papa *et al.* (2013) further allude that Networked TOD augments the traditional transport concept by stressing the synergy between the multiple TODs within a city network. This study endorses sentiments that indicate that networked TOD draws from the principles of TOD and urban network theory which view urban spaces as a system of links and interconnections (Talrej 2023). Urban network theory is the degree to which geographical concepts delineate the interconnectedness of urban space (Rozenblat 2020). Additionally, networked TOD is oriented within the principle of polycentric urbanism which prescribes the development of self-sufficient centres and multiple, and interconnected transport networks (Papa *et al.* 2013). This strategic approach has the potential to alleviate the dependence on a single central area and encourage more spatially balanced development.

2.2 *Urban corridors assessment for TOD nodes*

Urban corridor assessment for TOD nodes is an essential facet of recent urban planning. This is because global cities both in developed and developing worlds currently grapple with the challenges of rapid urbanization (Uddin *et al.* 2023). There is thus an emphasis on developing well-connected, efficient, and sustainable transportation systems that can stimulate economic development and improve quality of life. In urban planning, nodes mean the central development of a neighbourhood that is connected to its surroundings (Xie *et al.* 2022). According to Teklemariam and Shen (2020), the assessment of urban corridors plays a critical role in recognizing suitable locations for TOD nodes. Urban planners and scholars in the field have stressed the importance of an extensive evaluation of potential and existing corridors in the city. This should take account of crucial factors such as land use patterns, accessibility, transportation infrastructure, and socio-economic dynamics which are key in TODs (Harrison and Rubin 2020). The current study utilizes this factor to assess TOD nodes within the City of Johannesburg (CoJ). According to Khare *et al.* (2021), this assessment guides the selection of suitable areas for TOD. It also informs policies that encourage a comprehensive integration of land use and transportation, to foster a more resilient and sustainable urban fabric. Research in the domain of TOD nodes involves public participation to understand the communities' needs adequately and assess the potential impacts of TOD implementation on their lives.

2.3 *Polycentric TOD: Emerging concept and implementation challenges*

According to Chen (2022), polycentric transit-oriented development is an emerging concept in the arena of urban planning. Kumar, Ghosh, and Singh (2022) indicate that polycentric TOD in urban planning represents a paradigm shift that moves beyond the traditional monocentric city model. Polycentric TOD is emerging as the mechanism that addresses the challenges posed by rapid urbanization (Garde 2020). Moreover, in practice, polycentric TOD as a concept recognizes the limitations resulting from centralized development and visualizes a decentralized multi-nodal urban morphology. This approach reduces the dependence on a monocentral business district (CBD), encouraging a more sustainable and resilient urban morphology (Chen 2022). Ewing *et al.* (2020) indicate that principles governing polycentric TOD are drawn from polycentric new urbanism. According to Garde (2020), new urbanism is the design movement that seeks to improve the mobility of how cities are built. Therefore, polycentric TOD stresses the development of multiple centres of economic activities and improving city community life. The following section explains emerging concepts and challenges included in the implementation of polycentric TOD.

2.3.1 *Emerging concepts*

Polycentric TOD as an emerging concept showcases essential benefits including, 1) spatial equity and inclusion (Harrison, *et al.* 2019). By decentralizing amenities and economic opportunities connecting to other CBDs, polycentric TOD can provide a closer public transport hub to marginalized communities and can also reduce spatial inequality and enhance greater access to services and jobs for residents. 2) Resilience and economic diversification, indicate that the development of TOD in various existing CBDs can give rise to multiple economic clusters. This can foster economic diversification and alleviate economic vulnerability that can easily impact the dominant monocentric development Prestes *et al.* (2022). 3) Sustainable urban development through polycentric TOD can foster even more walkable and compact development patterns. This can also reduce private car dependence and enhance the interconnection of TODs (Liu *et al.* 2020). The fewer private cars there are on roads, the lower the carbon emissions and this will not only improve environmental sustainability but act as a measure to champion climate change.

2.3.2 *Implementation challenges*

Notwithstanding the potential benefits of polycentric TOD, the concept faces several challenges including, 1) governance and coordination, since polycentric TOD involves multiple nodes. Thus, developing and managing multiple centres necessitates strong coordination between community groups in a city, government agencies, and private developers (Maina 2020). These difficulties pose challenges for investment, planning, and adequate distribution of resources (Ewing *et al.* 2020). 2) Public transport infrastructure investment. Thus, developing a polycentric network requires robust public transport infrastructure investment (Higgins *et al.* 2021). 3) Overcoming path dependence involves the transitioning of areas that can become urban centres; therefore, these cities will be required to overcome the existing political and economic forces that favour the dominant centre. Overcoming these challenges will be difficult for any city, however, addressing them is crucial for a successful implementation.

2.4 *Urban corridors and TOD: Lessons from global practices*

Curitiba is the largest and capital city of the state of Parana, Brazil. Curitiba operates a well-integrated Bus Rapid Transit (BRT) system with TOD designed along its corridors (Vergel-Tovar and Landis 2022). The TOD in Curitiba, like the TOD in Johannesburg (Park Station), offers mixed residential, leisure facilities, and commercial land uses, attracting businesses and residents while fostering the sharing of ridership on a public transport network (BRT system). The reason why the study chose Curitiba as a counterpart to CoJ is due to the common challenges including the scale of informal settlements, investment and governance, and existing land-use and ownership. Curitiba has strong government agencies with strong policies that are strategically focused on implementation (Prestes *et al.* 2022). Moreover, these agencies are dedicated to overseeing TOD development and planning.

Essential elements of Curitiba's achievements include dedicated lines for BRT buses which physically separate the BRT bus from mixed traffic (Turbay *et al.* 2022). These lines allow the buses to drive with a greater required speed and reliability, improving travelling times compared to metro systems in the city (Prestes *et al.* 2022). The Curitiba urban corridor and TOD include the iconic tube station, these stations enhance the visual aesthetics and identity while adding a unique aspect to Curitiba's BRT. These tubes are stations like Johannesburg BRT (Rea Vaya) stations and facilitate speedy boarding through the multiple doors of the BRT buses. Curitiba also prides itself on its comprehensive network of the BRT systems, since its CoF has BRT components, the infrastructure in Curitiba is far more extensive (Topchiy 2017). Unlike the CoJ BRT, Curitiba BRT routes reach into the residential communities, and the designated lines strategically feed passengers to the different parts of the city, maximizing the accessibility of the system (Turbay *et al.* 2022). Curitiba BRT with its cubic bus station. The corridors and TOD in Curitiba are supported by coordinated land-use planning. Curitiba utilizes linear zoning as a planning strategy along the BRT corridors to foster mixed-use, and high-density (Prestes *et al.* 2022). This strategy guides development near the station, this adequately increases the ridership and encourages the use of public transport. Overall, the CoJ would greatly benefit from these zonings' transformations.

2.5 *Materials and methods*

A mixed method was adopted, combining both quantitative and qualitative data types. The study included interviews with six officials from different stakeholder groups (CoJ Department of Transportation and Johannesburg Roads Agency) and 20 diverse daily commuters. The participants were approached through a purposive sampling method to ensure that there was comprehensive engagement with participants. The interviews provided invaluable information for the development of a Spatial Network and Morphology Framework for Polycentric TOD in the CoJ. Data sources for this study included documented studies, observations, and interviews. Qualitative analysis was utilized to review the previous literature and channel the strategies identified into the study Spatial Network and Morphology Framework. Moreover, secondary information was gathered from credible databases such as Google Scholar, ScienceDirect, Scopus, and Sage.

2.6 *Results and analysis*

2.6.1 *Analyzing the corridors of freedom of the CoJ*

In considering this analysis it is noteworthy that the Johannesburg Mayor, Mpho Park Tau, launched the initiative of "Corridors of Freedom" in 2013. This was meant to develop both inclusive housing and transportation options in one spatial morphology to address spatial isolation in the city. The Rea Vaya bus rapid transit (BRT) system is the lifeblood of the CoF in the CoJ due to its recurring station and bus stops from Johannesburg CBD to Soweto. The CoF in the CoJ consists of the BRT and Gautrain systems, cycling infrastructure, and associated pedestrians that interconnect the historically underserved communities in the CoJ with the periphery of the city. Additionally, the CoF encompasses the development of mixed-use and mixed-income housing along the corridor from Johannesburg CBD to Soweto. This helps to integrate land use and transportation to serve the residents by fostering economic opportunities for residents through the development of urban spaces that equally host commercial enterprises in the CoF. Moreover, this development was tailored to move people close to their working environment or to their public transport hub which facilitated movement to any place. The CoF project in the CoJ was strategically approached through long and short-term objectives. The long-term project is still in progress to date, with expected completion by 2040. This strategy seeks to extrapolate the CoF to areas such as Ivory Park and Dieploot, these areas are highly densified in terms of population yet underserved communities in the city. The medium-term strategy included development from Soweto to the CBD to Alexandra and

Sandton, Turffontein node, Perth Empire, and Mining Belt. Corridors radiating outward from the CoJ, as the map illustrates the Soweto development corridors. These include the Empire Perth Development Corridor, Turffontein Development Corridor, Louis Botha Development Corridor, and Sandton. The corridors are strategically anchored by the arterial road or Highway to facilitate accessibility and movement, with a Rea Vaya BRT line in some of the corridors. The CoF connects the Johannesburg CDB to the peripherals, whilst facilitating economic inclusion throughout the city.

2.6.2 *Suitable areas for TOD in the CoJ*

The interviews with the community of the CoJ and its officials revealed that brownfield areas surrounding the Rea Vaya public transportation hub in the CoJ CBD are highly appropriate for a mixed-use TOD development. These brownfield sites were previously occupied by industries. The study also showed that densely populated townships and suburbs along major transport corridors like Alexandra, Soweto, and Mayfair with existing Rea Vaya and other buses existing routes will adequately support TOD initiatives. This will allow the TOD to enhance the existing station's access, walkable environment, and mixed-use development. Moreover, areas surrounding Metrorail, and Gautrain stations with existing commercial development can also be suitable for suitable TOD projects, integrating office spaces and residential areas and promoting vibrant entertainment and further economic stimulation. TOD promotes symbiotic relationships between the compact and dense urban form and the use of public transportation.

2.7 *Spatial network and morphology framework for polycentric TOD*

The study reveals the strong preferences for TODs. Therefore, key elements are proposed that support relocating the suitable areas for TODs within the CoJ. These include public transport accessibility, land use with development potential, and socioeconomic considerations. This framework advocates for the use of land closer to the public transportation hubs such as BRTs, midi-bus (taxi), and rail stations to encourage walking to the public transit hubs. The CoJ Joburg 2021 SDF regulates 500 m as the distance from TODs to a public transit station. This study equally encourages a 400 – 600 walking radius of TODs to further promote the principle of walkability and cycling. Using the collected data and the results, the following is the proposed model used to select suitable areas in Johannesburg. This section will further illustrate the framework as a point of departure, showcase the CoJ current structure, and then showcase the envisioned city structure.

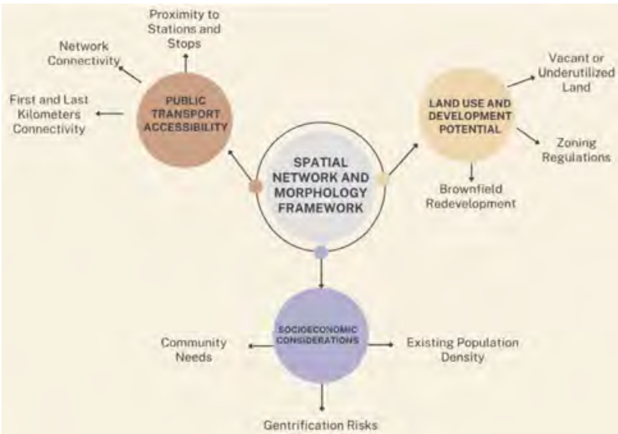

Figure 1. Spatial network and morphology framework for polycentric TOD [Source: Author (2024)].

This framework promotes urban renewal within the CoJ by encouraging the reusing of land or buildings for TOD, to alleviate the demolition of buildings, and rezoning to promote mixed-use development. According to the framework, areas with a higher-density of population, TOD can support them through the mass of readership and further integrate the commercial land use.

2.7.1 *Johannesburg's current metropolitan structure of inverted polycentricity*

The CoJ's current metropolitan structure illustrates its 'inverted polycentricity'. Polycentricity is a planning concept which challenges the monocentric city morphology to foster multiple urban nodes. The current polycentricity of CoJ can be observed as a dominating central core with the CBD, and the principal metropolitan center ranging from 12 to 25 kilometers to the periphery of the city (See Figure 2). This polycentricity concentrates on encouraging economic activities focused on the CBD, limiting accessibility for residents who are located on the outskirts of the city.

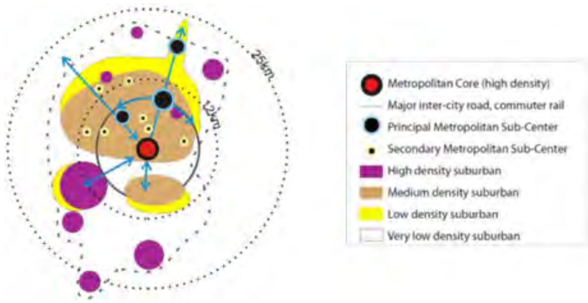

Figure 2. The current polycentricity of CoJ [Source: CoJ Draft Spatial Development Framework 2040 (2022)].

The current structure indicates that the city has urban nodes, but they do not possess TODs, therefore the study anticipates searching for suitable areas to support TOD in a polycentric form of city structure. This structure will have advantages through the movement of decentralizing resources and services to the periphery of the city from its center and corridors whilst enhancing accessibility. Developing a network of TODs in these corridors can foster transit-shared ridership, promote sustainable urban development, and develop a vibrant city node. The CoJ can progress in a sustainable and inclusive urban form which leverages the strength of its existing morphology.

2.7.2 *Johannesburg future city model: Compact polycentric urban form*

The CoJ envisions a far-reaching spatial transformation towards a sustainable, compact polycentric urban form. Additionally, the future metropolis includes a network of interconnected urban nodes, amenities beyond a single dominant core, and an equal distribution of economic activities. The future city model entails higher density development supporting the existing mixed-use which characterizes the core, whilst the subcentres are moderately densified. A comprehensive public transport system connects everything with the city, potentially including rapid transit lines which foster accessibility and permit effective integration of transportation and land use. The envisioned city model adequately integrates land use with green spaces, which advocates for environmental sustainability. This polycentric method promises a multitude of benefits. These would include a reduction of private vehicle use, enhanced accessibility into the city, decentralization of development opportunities, resilience against economic shocks due to urban nodes that are economically strong and increased social equity with resources distributed evenly. Figure 3 is the envisioned city model.

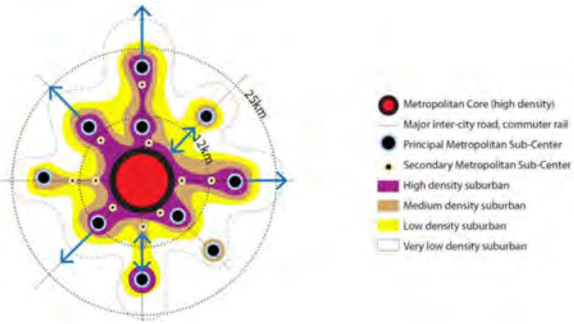

Figure 3. The current polycentricity of CoJ [Source: CoJ Draft Spatial Development Framework 2040 (2022)].

It is however important to note that this model relies heavily on robust infrastructure investment, increment on public transportation modes, and more focused integrated development across these new centres. This envisioned city structure capitalizes on this model to simulate suitable areas to support a polycentric TOD city. Therefore, the successful implementation of the polycentric TOD is anchored on extensive community engagement, to serve the needs of citizens. Overall, this vision presents a comprehensive path towards a more equitable, well-integrated, and sustainable Johannesburg.

2.7.3 *Existing Johannesburg urban nodes*

The CoJ has 42 nodes excluding the CBD, this reflects what the paper has indicated, namely an "inverted" polycentric city form. This means that the CoJ has one prominent CBD with supporting scattered secondary centres (nodes). Conversely, the polycentric approach is prone to distributing the amenities and economic opportunities across the multiple connected nodes. A polycentric city would also lessen the urban pressure on the CBD, enhance mobility and accessibility for residents in the peripheral areas, and lead to a more equitable city. TOD is essentially pivotal in achieving a polycentric urban form. Areas such as Diepsloot, Kliptown, Randburg, Bruma, Jabulani, and Roodepoort are close or far from the CBD, but they have planned public transport lines and vacant land and include a mix of residential and commercial land including other nodes, thus making them prime candidates for TOD. These areas were identified by the Spatial Network and Morphology Framework for Polycentric TOD presented above.

2.8 *Suitable areas for TOD development: The Jozi-web*

With the collected data and the use of Geographical Information Systems, the study has formulated a framework to comprehensively identify suitable areas for TOD development in the COJ nodes. These areas are selected based on the key elements endorsed by the Spatial Network and Morphology Framework for Polycentric TOD which include public transport accessibility, land use and development potential, and socioeconomic considerations. According to the framework, these areas exhibit the characteristics that make them well-suitable for TOD implementation and support the polycentric transformation of the city. The following, answers the question: How these were selected through the framework? The framework was developed through the results of the study, and then 42 nodes were researched using secondary information along with their public transport accessibility, land use and development potential, and socioeconomic as the key performance indicators benchmarking. The study also found that other areas are suitable to support polycentric urban forms in the city. Albeit the question has been addressed. The following Figure 4 is the map that shows the selected suitable areas within the CoJ.

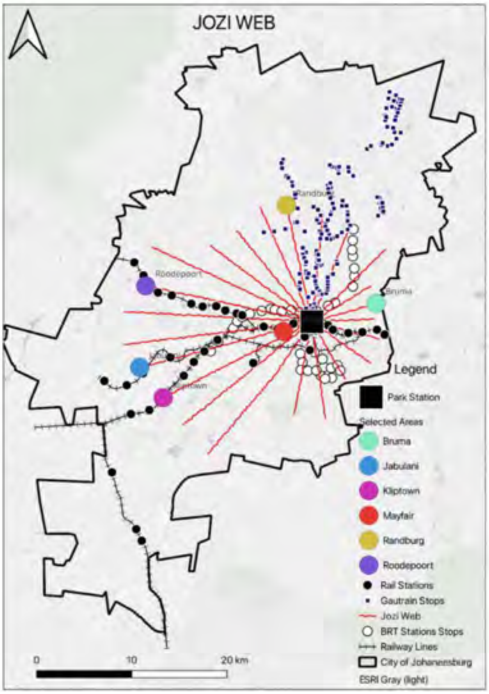

Figure 4. Map showing selected noted for TOD development [Source: Author, (2024)].

Consequently, all these areas (Diepsloot, Kliptown, Mayfair, Randburg, Bruma, Jabulani, and Roodepoort) are strategically situated along planned public transport spaces or corridors, ensuring swift mobility and connectivity. This connective framework ought to be called, the “Jozi-Web”. The strategic location within the Jozi-Web is already existing, therefore, as these areas are suitable for TOD, they are equally integrated with the city’s public transport network. Alongside what these areas possess it is important that they have vacant land to adequately develop TOD. Overall, the Jozi-Web is a coined terminology through the observation of how the roads in the CoJ connect from the maps.

3 DISCUSSION

The study’s results yielded the potential transformation of Networked Transit-Oriented Development (NTOD) in addressing urban challenges in the city of Johannesburg. The findings underscore that the NTOD adequately fosters sustainable mobility and reduces carbon emissions through car dependence, this is vital for the city to mitigate traffic congestion and address environmental challenges. The identified key areas within the city that are suitable for TOD node development are selected through the model, to provide a target for urban planners. Subsequently, the development of the Jozi-Web framework indicates the practical model for achieving a polycentric urban structure with the aim of fostering interconnectedness and accessibility throughout the city. This framework is innovative, and it does not only address the city’s current spatial fragmentation but is also sets out the stage for a more balanced and equitable urban growth, aligning with the global trends towards decentralization and sustainable urban development.

4 CONCLUSIONS

To conclude, the study's results underscore the importance of a polycentric design, as it supports the city's ultimate goal which is transforming the spatial layout. By implementing TODs in areas such as Jabulani and Mayfair, the Jozi-Web encourages more sustainable urban development, evenly balanced economic opportunities distribution, and enhanced mobility and accessibility. This method paired with the polycentric principle and the existing corridors, stands as a strategy to alleviate congestion in the CoJ, develop equitable and vibrant neighbourhoods, and drive the city towards a more resilient and sustainable urban development future. TOD integrates well with land use; therefore, a networked TOD will equally complement land use practices in the CoJ in the future.

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Challenges of implementing biophilic design principles in hospital infrastructure development: A review

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ABSTRACT: The implementation of biophilic design principles and strategies has become a popular and acceptable idea in both developed and developing economies. While studies acknowledge the potential of biophilic design in hospital settings, the implementation of biophilic principles in developing healthcare infrastructure faces numerous challenges that are neither highlighted nor well documented. This study examined important issues that typically limit the use of biophilic features, based on a review of published literature. The study identified regulatory compliance and cost constraints as the main categories of challenges faced in the implementation of biophilic design. The study recommends awareness and engagement of all stakeholders from the design stage to the implementation stage and post occupancy evaluations, as well as financial incentives to encourage the adoption, innovation and development of specialized skills and business ventures in biophilic design and sustainable infrastructure development.

Keywords: Biophilic Design Principles, Biophilic Design Challenges, Hospital Infrastructure, Built Environment, Review

1 INTRODUCTION

The major point of biophilic design in architecture is to create a close relationship with nature in order to improve people's health and productivity. These guidelines promote peaceful coexistence with nature through the integration of natural elements into the built environment. The fundamental concepts of biophilic design are as follows: visible and physical (Bahador 2023), indoor-outdoor relationship with the natural environment (Chawla 2012), organic forms and designs (Djouad 2021), natural light and natural ventilation (Gillis and Gatersleben 2015), natural and locally sourced building materials (Jaheen and El-Darwish 2021), use of water elements (Alam 2023), as well as multisensory and cognitive functional spaces (Peters and D'Penna 2020). Applying these biophilic design concepts, architects and designers may create environments that enhance human health, well-being, and productivity while simultaneously forging a robust and long-lasting bond with the natural world.

According to Untaru, Ariza-Montes, Kim, and Han (2022), the application of biophilic design principles in healthcare environments has been shown to improve recovery outcomes, lower stress levels, and promote well-being. Research indicates that having a view of the outdoors and incorporating biophilic patterns into healthcare settings, directly improves people's well-being, reduces discomfort, and speeds up their recuperation from disease and operation procedures. Research indicates that biophilic elements, such natural light,

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vegetation, and access to nature, can help patients heal more quickly, experience less mental stress, tolerate pain better, and spend less time in the hospital (Untaru 2023). As a result, biophilic design is becoming more and more important in the healthcare industry, because it is seen to humanize healthcare spaces and thus enhancing emotional well-being and improving the overall experience for both patients and healthcare professionals (Kellert 2015). Totaforti (2018), further explained that well-known medical facilities that demonstrate the successful application of biophilic design in hospitals have improved patient outcomes and experiences as a result.

Studies have shown that using biophilic design principles in hospital infrastructure can help solve a variety of problems and improve the overall resilience of healthcare settings. Biophilic design architecture makes a significant contribution to the design of resilient infrastructure for hospitals by incorporating natural elements that improve the well-being of patients, staff, and visitors while also increasing the resilience of healthcare facilities. Biophilic design architecture is essential for building resilient hospital infrastructure in the following domains: enhancing healing environments (Purani and Kumar 2018), improving resilience to disasters (Sunindijo *et al.* 2019), promoting sustainable practices (Achour *et al.* 2014), fostering collaboration and innovation (Guzzo *et al.* 2022) and addressing stakeholder needs (Bergerød *et al.* 2022).

1.1 *Aim and objectives*

Despite the fact that previous studies acknowledge the potential of biophilic design in hospital settings, the implementation of biophilic principles in healthcare infrastructure is faced with many challenges that are neither highlighted nor well documented. Therefore, there is limited knowledge about the challenges of implementing biophilic design principles in hospital infrastructure development. This study aimed at bridging this knowledge gap, drawing insights from an extensive review of published literature, dissecting the hurdles and limitations inherent in applying biophilic design principles within hospital environments, focusing on three main objectives. Firstly, delineating the many challenges encountered while implementing biophilic design strategies in hospitals, as documented in existing scholarly works. Secondly, categorizing these difficulties and identifying recurring themes and patterns in various sources; and lastly, to spotlight the primary barriers observed in executing biophilic design strategies in hospital contexts.

Through achieving the said objectives, the study contributes not only in addressing the theoretical knowledge gap in biophilic design principles and hospital infrastructure, but also offers valuable insights that can inform decision-making processes and facilitate the formulation of standards and regulations to promote sustainability and resilience in hospital infrastructure development.

The study encourages innovation and the development of specialized skills and business ventures in biophilic design and sustainable infrastructure by pushing architects, engineers, contractors, and other construction professionals to devise design solutions and develop construction strategies that address implementation challenges. The research provides more support for the application of biophilic design, thereby advancing sustainability—a critical component for developing nations confronting environmental concerns. Greener urban development can be promoted and energy consumption can be decreased by implementing biophilic concepts in improved hospital designs.

With practical insights for all parties involved, the study provides a thorough understanding of the challenges to implementing biophilic design in hospitals. It also offers an educative platform for decision-makers on the advantages and difficulties of biophilic design, resulting in laws and incentives that encourage the construction of sustainable healthcare infrastructure. The study is also a useful resource for academic institutions to use as teaching material for improving courses on sustainable development, architecture, and healthcare administration.

2 METHODOLOGY

The research is a literature review that made use of qualitative research methodology. The conduct the study, five steps were used. Step one involved identification of the research problem and aim of the study. The second step was the development of research objectives to achieve the aim of the study. Step three involved gathering of data from secondary sources such as published literature in Scopus, Science Direct, and Google Scholar, to identify and categorize the different causes of challenges in implementing biophilic design in hospitals, using the following keywords: biophilic building principles, hospital design, implementation challenges, causes and limitations. The fourth step involved gathering of 105 documents published between 2007 and 2024 that were selected based on a review of their topics and abstracts that contain related thoughts to the purpose of the study. The fifth step involved the selection of 30 of the documents that eventually constitute the sample size of literatures reviewed and data collected from them, after a careful scrutiny of their text. The data was content analysed by theme analysis using descriptive approach. The results were presented in themes with a table and a diagram to facilitate understanding.

3 RESULTS AND DISCUSSIONS

Implementing biophilic design in architecture can be challenging due to various building design constraints. These challenges can hinder the seamless integration of natural elements into the built environments, impacting the effectiveness of biophilic design principles. To compound these challenges, there is limited knowledge on the causes of the difficulties involved in using biophilic design concepts in hospital environments. There is also no clear understanding and documentation of the number of causing factors and their categories, associated to the planning, design, construction and operation of hospitals. To bridge this knowledge gap, 15 different causes of challenges to biophilic design in hospitals were discovered as presented in Table 1.

Table 1. Causes of challenges in the implementation of biophilic design strategies in hospitals arranged according to rating, based on the number of publications identifying the causative factor.

No.	Causative factor	No. of articles	Rating	Sources
1.	Building Codes, Standards, Guidelines and Regulatory Compliance	8	1st	10,14,17,19,33,37,38,42
2.	Cost Constraints including initial, operational, return on investment, cost benefit analysis and maintenance costs	7	2nd	16, 25, 26,27, 28, 29,39
3.	Maintenance and operational requirements, including plan care demands, operational efficiency, indoor air quality and environment	6	3rd	14,16,35,36,37,40
4.	User preferences	5	4th	9,15,21,23,41
5.	Space limitation	2	5th	10,16
6.	Adaptation to Local and Urban Contextual issues	2	5th	12
7.	Infection Control Measures	2	5th	31,34
8.	Structural limitations	1	6th	16
9.	Technical expertise	1	6th	17
10.	Climatic adaptations	1	6th	12
11.	Symbolism and meaning	1	6th	23
12.	Spiritual and ritualistic practices	1	6th	23
13.	Historical Context	1	6th	22
14.	Perception of nature	1	6th	20
15.	Functional Requirements	1	6th	20

From the data displayed in Table 1, the main categories of challenges were the building codes and costs contains, followed by maintenance requirements and user preferences issues faced in implementation of biophilic design in hospitals, especially in developing economies. The causes of the challenges identified in implementing biophilic design strategies in hospitals were categorised under seven main groupings as illustrated in Figure 1.

Figure 1. Categories of causes of challenges in implementation of biophilic design strategies in hospitals.

The seven categories of the causes of the challenges of implementing biophilic design strategies in hospital developments are examined as follows:

3.1 *Building design and considerations*

Incorporating biophilic design elements, such as green roofs, natural materials, and water features, into a building will result in higher construction and maintenance costs, which will present financial challenges for the project's implementation. The integration of large-scale biophilic components, such as abundant vegetation or indoor gardens, may be restricted in building designs with limited space, hence restricting the possibility to create immersive natural environments. Due to structural limitations and retrofitting difficulties, existing building structures might not be suitable for implementing biophilic features, such as natural light optimization, ventilation systems, or living walls. It can be difficult to maintain biophilic elements like living walls, water features, and vegetation over time, especially in commercial buildings or high-traffic areas (Guzzo *et al.* 2022). According to El-Baghdadi and Desha (2017), the application of some biophilic design components may be hampered by building rules and laws, particularly in urban settings where zoning limits and environmental requirements must be taken into account. It might be difficult to find the specific knowledge and technical expertise experience needed to design and execute biophilic features in fields like landscape architecture, ecological design, and sustainable building techniques (Mahrous *et al.* 2022). Striking a balance between biophilic design components, user preferences, and functional requirements can also be challenging since different people may have different views on how to integrate nature, which could affect the design's overall success (El-Bannany *et al.* 2022). The viability of some biophilic aspects is also determined by local climates and ecosystems, since certain natural features might not flourish or be viable in particular climatic conditions (Parsaee *et al.* 2020).

3.2 *Cultural considerations*

Different cultures interpret colours, patterns, and natural elements metaphorically. Misunderstandings or resistance may occur when biophilic design elements go against cultural norms or beliefs. Because cultural aesthetics and design traditions vary by region, biophilic design needs to cater to local tastes in order to be well-received. When working with particular cultures, it can be challenging to find a balance between spiritual considerations and design aesthetics because of their ritualistic or spiritual connections to nature, which have an impact on how biophilic design is viewed and used (Tomasso *et al.* 2021). The influence of historical and cultural legacies on design decisions is profound. When integrating biophilic elements, a location's cultural legacy must be honoured and reflected, which necessitates significant thought and understanding. In order to successfully integrate biophilic design within the specific cultural and environmental context, considerations such as climate, location, and cultural norms must be made (O'Sullivan *et al.* 2023). Effective design must include local communities in order to understand the needs, customs, and values of the community. Socioeconomic disparity and resource availability impact the viability and adoption of biophilic design, making it challenging to maintain cultural values while ensuring affordability and inclusivity (Ferreira *et al.* 2020). Since diverse cultures have differing viewpoints on nature, the wilderness, and urban green spaces, it is challenging to apply biophilic design to create inclusive and culturally sensitive ecosystems (Barbiero and Berto 2021).

3.3 *Economic considerations*

One of the greatest challenges is the cost of implementing biophilic design components in hospitals. The initial cost of adding natural elements like plants, water features, and natural materials can put healthcare facilities in a tough financial situation. Funding biophilic design projects may have to compete with other important medical expenses due to the rising cost of hospital operations. Finding a balance between healthcare facilities' overall financial constraints and the costs associated with integrating biophilic design can be challenging (Dion and Evans 2022). It might be difficult to prove the financial advantages of biophilic design in healthcare settings. Hospital administrators may need to provide proof of the financial gains from biophilic design, such as better patient outcomes, lower operating expenses, and higher employee satisfaction (Shin *et al.* 2022). Dion and Evans (2023) stated that, given competing demands for healthcare, integrating features inspired by nature necessitates careful resource allocation and prioritisation. Water components, green roofs, and living walls are examples of biophilic design elements that need constant upkeep and attention. Hospital finances and resources may be strained by the ongoing operating expenses related to preserving biophilic features (Gola *et al.* 2020). It is imperative to carry out a comprehensive cost-benefit analysis prior to introducing biophilic design in hospitals. While assessing the financial effects, possible savings, and advantages of biophilic design projects can be difficult, doing so is essential for making decisions (Almusaed *et al.* 2022).

3.4 *Regulatory compliance*

To safeguard patients, hospitals are required to adhere to stringent infection control protocols. According to Tekin, Corcoran, and Gutiérrez (2022), biophilic materials, like plants and water features, have the potential to harbour bacteria and pathogens, making infection prevention and hygiene more difficult. Hospital design must adhere to healthcare regulations and construction norms, which may restrict biophilic features like big windows or green walls because of fire safety regulations, privacy concerns, or structural integrity issues (Mahrous *et al.* 2022). In order to prevent maintenance problems or safety hazards, biophilic aspects must be carefully studied. Patient and staff safety is of the utmost importance (Mollazadeh and Zhu 2021). The incorporation of biophilic characteristics may be impacted by noncompliance with healthcare standards, especially with regard to cleaning and maintenance (Untaru *et al.* 2022). Finding a balance between the therapeutic benefits of biophilic design and the functional needs of healthcare facilities like patient care and workflow efficiency, can be challenging. Ensuring accessibility for patients with disabilities or mobility challenges is crucial, as some biophilic features may not comply with accessibility criteria (Zhao *et al.* 2022).

3.5 *Operational issues*

In order to remain healthy and dynamic, biophilic design elements such as living walls, vegetation, and water features need to be maintained on a regular basis. Hospitals must set aside money for continuing, labour and money, intensive plant maintenance such as pruning, watering, and pest control. Understanding horticulture is crucial for integrating greenery into medical settings, guaranteeing plant development, controlling seasonal changes, and preserving the health of indoor plants (Ebekozien *et al.* 2021). Hospitals prioritize interior air quality in order to keep visitors, employees, and patients in a healthy environment. Because adding biophilic elements might alter humidity, air circulation, and allergens, it is essential to monitor and manage them appropriately (Jandali and Sweis 2018). Hospitals must implement strict infection control protocols in order to stop the spread of infections. Biophilic elements, especially water features and plants, might make microbiological control and cleaning more difficult, necessitating the use of strict infection control methods (Gola *et al.* 2019). It's critical to strike a balance between the aesthetic advantages of biophilic design and operational efficiency. To guarantee that biophilic elements do not compromise patient safety, interfere with workflow, or prevent access to medical equipment, careful design and integration are required. Respecting the legal requirements for infection control, indoor air quality, and facility upkeep is essential. Observing these guidelines combines biophilic elements with patient safety (Yousefli *et al.* 2017).

3.6 *Spatial constraints*

Hospitals often lack the space required for biophilic features like plants, water features, and natural materials, especially when located in urban areas. The implementation of biophilic design concepts, which involve gardens, plants, and outdoor areas, is impeded by spatial limits (Untaru *et al.* 2022). The integration of biophilic features in urban hospitals can be hindered by restricted access to green spaces and natural surrounds (Tekin *et al.* 2022). Also, Urban hospitals' emphasis on interior spaces often restricts options for biophilic elements like views of flora, outdoor access, or natural light, affecting indoor biophilic design (Zhao *et al.* 2022). Careful design is necessary to ensure that biophilic features are accessible to patients, staff, and visitors in hospitals with limited space (Cabanek *et al.* 2020). It is difficult to incorporate biophilic elements while achieving operational goals in hospitals since they have special functional needs that must be met in small areas (Barbiero *et al*. 2021). Due to the potential negative effects of space limitations on patient experiences and health, innovative approaches to creating healing spaces with biophilic elements in compact spaces are required (Untaru 2023).

3.7 *Stakeholders' resistance*

Hospital managers, staff, and patients are examples of stakeholders who may not fully understand the concepts of biophilic design. Another potential source of resistance is a lack of understanding of the benefits of incorporating nature-inspired features into healthcare environments. The application of biophilic design may result in perceived disruptions to current hospital operations, which may be the source of resistance. When changes are seen as a threat to established procedures and workflows, stakeholders may oppose them. Hospitals may need to make additional investments in order to implement nature-inspired aspects, and stakeholders may be reluctant to commit funds in the absence of convincing cost-benefit analyses (Edwards 2023). Diverse aesthetic preferences among stakeholders can also create resistance to nature-inspired design elements (Prugsiganont and Waroonkun 2021). Operational concerns, such as higher maintenance needs for vegetation and infection control issues, may further oppose biophilic design (Kilaru *et al.* 2022). Stakeholders may also resist biophilic design if it contradicts existing rules or conventions in healthcare facilities. Resistance is often exacerbated by inadequate stakeholder participation and insufficient information about the benefits of biophilic design. Effective communication strategies are essential to address concerns and gain support for biophilic initiatives (Shepley *et al.* 2022).

4 CONCLUSION AND RECOMMENDATIONS

This review identified and categorized the different causes of difficulties and limitations involved in using biophilic design concepts in hospital environments. A number of causes of the challenges in implementing biophilic design strategies in hospitals were identified from published literature. The review identified regulatory compliance and cost constraints as the main categories of challenges followed by maintenance requirements and user preferences issues faced in implementing biophilic design in hospitals, especially in developing economies. In addition, seven categories of the causes of the challenges in implementing biophilic design strategies in hospitals were discovered and examined. They include: building design considerations, cultural considerations, economic considerations, regulatory compliance, operational issues, spatial constraints and stakeholders' resistance.

To address the challenges of implementing biophilic design principles in hospital infrastructure development, the study recommends the following: First, efforts should be made by building professionals to create awareness and engagement of all stakeholders from the design stage to the implementation and post occupancy evaluations stages. Second, government agencies managing innovative discoveries should provide financial incentives for incorporating biophilic features and for encouraging innovation and development of specialized skills and business ventures in biophilic design and sustainable infrastructure. These efforts are likely to push professionals more, to devise design solutions and develop construction strategies that address implementation challenges.

Through achieving the objectives of this study, the paper contributes to advancing knowledge by providing more illumination towards understanding the causes of the challenges associated with biophilic design in healthcare settings. Moreover, it has provided useful insights that can inform decision-making processes and facilitate the development of standards and regulations to promote sustainability and resilience in hospital building design. The study recognizes that literature review has limitations, especially in the fact that it uses secondary data. However, this does not negate the contributions of the study. In order to overcome this obstacle and encourage the incorporation of biophilic design concepts in hospital environments, the review concludes by highlighting the importance of further research on interdisciplinary cooperation, creative solutions, and evidence-based tactics on the implementation of biophilic design strategies in hospital settings. The study further recommends that research should be carried out to identify and analyse the causes of limitations in application of biophilic design from a selected sample of hospitals within one of the growing economies.

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Assessment of informal settlement in Musanze District, Rwanda. Towards sustainable urban development

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ABSTRACT: Over 30% of the world's population resides in informal settlements, lacking urban infrastructure, essential services and are often located in risky areas. These settlements are prone to socio-environmental disasters, pollution from industrial activities, and hillsides without proper management. This research aimed to assess the factors and impacts of informal settlements in Musanze, Rwanda, using a sample size of 361 households. 5-point Likert scale questionnaires were used and analysed through SPSS. Findings indicated some level of agreement from the sample size, concluding that informal settlements were located in hazardous areas with steep slopes, affected by natural disasters, and impacted by structural and locational factors, affecting property values and difficulty in assessing tax, hence resulting in low level of revenue collection required for service provision. The study concluded that sustainable urban development is necessary, requiring efficient land planning and regulation systems to provide affordable housing for the growing population resulting from urbanisation.

Keywords: Informal settlement, Sustainable, urban development, infrastructure development, Musanze

1 INTRODUCTION

The problem of informal settlement is a well-known challenge affecting over 30 per cent of the world's urban population (Aboulnaga *et al.* 2021). These communities have grown remarkably, and despite 50 years of government intervention in most countries, their expansion has not been controlled. Most emerging cities cannot survive without them because of how economically, geographically, and socially interconnected they are with their urban environments; nonetheless, there is a persistent urge to remove them, which concerns place identification and urban imaging concerns. In third-world nations, informal settlements and urban informality are significant issues. They significantly impact the housing supply and demand market and are mainly formed due to rising housing demand and shortage of affordable housing supply. Informal settlements are residential places where residents live non-responsibly, ranging from informal house rentals to illegal residences (Williams *et al.* 2019). They are frequently formed and carried out without considering town planning strategies; hence, in most cases, they are considered illegal. The relationship between legality and illegality in informal settlements is complex, and it allows for the

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simultaneous existence of self-built housing and settlements formed through illegal land invasion with the informal subdivision of highly valuable land that has been legally acquired or transferred (Sarrafi and Kheyroddin 2022). This complicates the urban system, as land markets, government, and many public and private players are involved. The impact of this phenomenon demonstrates the need for further thought and investigation into the notion that informal is merely the contrary of formal. Buildings not protected by the state or under government control or regulation are subject to this kind of illegality.

These settlements are characterised by most homeowners frequently ignoring safety laws. These dangerous locations are vulnerable to socio-environmental disasters, located near polluting industrial activities, slopes that are not well managed, river banks that are prone to flooding, and typically lack basic urban infrastructure and services, among other factors (Anwana *et al.* 2023; Corrall 2010). Informal settlement falls into two recognised qualifying categories: semi-formal and slum (Aboulnaga *et al.* 2021). The most impoverished and disadvantaged type of informal settlements are slums. They are characterised by extreme poverty and enormous clusters of run-down dwellings in the riskiest metropolitan areas near factories, landfills, swamps, degraded soils, and flood zones. Slum residents also face continual threats of eviction, illness, and violence in addition to a lack of public space, vegetation, and essential infrastructure and services, including tenant instability. This informal settlement, among many other factors, is caused by Urbanization. In certain places, migration has accelerated urbanisation and fast population growth. Developable land has not been made available through the official land delivery channels at a pace that keeps up with population expansion. Informal settlements grow due to an increasing urban population and housing demand. In that instance, most developing-nation cities have found it challenging to keep up with the pace of infrastructural planning and development necessary to meet the demands of an expanding populace (Kranthi and Rao 2009). This creates enormous issues for governments and ordinary individuals, as most rapidly expanding metropolitan regions already have high poverty levels, unemployment, informality, environmental risk, and housing and service backlogs (Williams *et al.* 2019).

Poverty and social isolation are the primary characteristics of informal settlements. Because residents of these settlements are typically lower-income earners, their limited financial capacity affects them, and they ultimately sell their houses at low prices to meet their requirements (Ferlan *et al.* 2017). Lack of access to basic urban services, like water and sanitation, in informal settlements drives away potential tenants and forces property owners to sell at prices below market value. Additionally, because informal settlements are unplanned and thus uncared for, the absence of these essential services hinders potential tenants and lowers property values (Castro *et al.* 2015). Although those without unquestionably dependable employment cannot find inexpensive houses to buy or rent within their community, informal settlements typically lower real estate prices. Some poor urban people who want to live in cities are forced to leave their homes and dwell in informal settlements because of their income and the high land cost. The social and economic well-being of the residents, as well as the overall functioning of the land market, are impacted in different ways by these well-established informal settlements (Bizimana *et al.* 2012).According to the characteristics of the unofficial settlements present in certain metropolitan regions, most specialists in urban housing have deduced that it is more reasonable to upgrade the infrastructure in these neighbourhoods rather than demolish the current buildings and construct serviced towns in other locations. A thorough investigation revealed that the initial plan of clearing the existing structures and then redeveloping is not financially possible, considering the local households' investments already made (Bah *et al.* 2018).

In Rwanda, land is still the sole property of the state, and the government has the authority to use, develop, and occupy it through a system of permits. When land leaseholders in urban or suburban regions cannot develop their plots of land for housing, the state is authorised to acquire the land since it still holds eminent ownership of the land. The government of Rwanda attempted to implement various measures, including expropriation and relocation, to enforce building regulations following the master plan for the implementation area and to maintain property value by providing essential features and establishing various land reforms, laws, and policies that govern the land market. Rwanda has been utilising master plans as a tool for urban planning, but it has not given the land needed for housing or measures to raise the value of residential real estate. Several factors led to the development of informal settlements, including the most dangerous places, fast urban growth, and boundary reform (Kohli *et al.* 2016). This results in most people occupying land without properly managing its land use. In light of this situation, property values appear low due to underdeveloped infrastructure, including power, water, and transportation systems. However, some improvements and developments have been made to the land to control the spread of informal settlements and increase the value of residential property in Rwanda. Several parties in Kigali, including the government, Rwanda Housing Authority, and the Ministry of Infrastructure, have concentrated on building new homes and improving urban infrastructure (Manirakiza 2014).

Given an overview of unplanned settlements, it is essential to consider the implementation of sustainable urban development. Sustainable urban development is critical for addressing the issues of growing urbanisation, such as affordable housing, infrastructure, and environmental impact (World Bank 2023). Sustainable urban development is commonly defined as development that meets the needs of present generations without compromising the ability to meet the needs of future generations (Jones 2017; Keeble 1988). It aims to build cities and towns that benefit human and environmental health in the long run. Sustainable infrastructure is defined as planned, designed, built, operated, and decommissioned systems to ensure economic, financial, social, environmental (including climatic resilience), and institutional sustainability over the full infrastructure life cycle (UNEP 2024). These two concepts go hand in hand, as sustainable urban development cannot be achieved without sustainable infrastructure development. However, to attain the goal of sustainable urban development, key strategies include protecting and restoring natural ecosystems in urban settings and creating communities that foster human potential—managing land and resources wisely. Unplanned settlement comes with challenges that make it almost impossible to achieve sustainable urban development. Elgohary *et al.* (2024) state that three branches of sustainable development (environmental, social, and economic) satisfy the requirements of the present generation without jeopardising the future generation’s ability to achieve their own needs and aspirations. These can be used to address the issues of informal areas, and their study proposed a checklist of sustainable development principles responsive to the characteristics of informal settlements by identifying informal areas’ sustainable development concepts, which are divided into four categories: economic, social, environmental sustainability, and quality of life, as well as evaluation and maintenance. Economic sustainability encompasses fundamental needs, employment and productivity; social sustainability concerns health, education, community safety, equality, freedom of choice, and participation. Environmental sustainability includes transportation, earth and soil, electricity, water, natural resources, waste, building infrastructure and sewerage. At the same time, quality of life is more concerned with evaluation and check-ups.

In order to assess the informal settlement factors and impacts, the study aimed to establish and assess the level of household agreement in Musanze to factors and impacts as highlighted through the use of a 5-point Likert scale; the study brings to light issues which are prevailing in the context of developing nations in Africa with a unique focus on Musanze district.

2 MATERIALS AND METHODS

2.1 *Study area*

This study was conducted in the Musanze district, an urban area with a high urbanisation rate. Nestled in the northern region of Rwanda, Musanze district is a captivating area spanning 530.3 square kilometres. Home to a population of 476,522 people according to the

2022 census, the district's landscape is characterised by its lush hills and valleys. With a population density of 898.6 individuals per square kilometre, Musanze thrives as a bustling activity centre. The district has experienced a modest annual population growth rate of 2.6%, indicating a stable demographic trend. Informal settlements are a notable feature of Musanze's social landscape, housing a significant portion of the district's population. These settlements, marked by makeshift dwellings, represent both resilience and challenge within the community. Inhabitants of all ages navigate the complexities of daily life amidst the backdrop of Musanze's natural beauty.

Musanze's demographic composition reflects a diverse range of age groups, with a notable concentration of youth. The district's urbanisation is balanced, with 242,264 residents in rural areas and 234,258 in urban centres, blending tradition and modernity. The district's climate is moderate, with an average annual temperature of 15.9°C (60.6°F) and an annual rainfall of approximately 1845 mm (72.6 inches). February stands out as the warmest month, with an average temperature of 16.4°C (61.5°F), while November is the coolest, averaging 15.4°C (59.8°F). Musanze district embodies a harmonious coexistence of nature and human habitation, where the rhythms of life intertwine amidst the scenic beauty of the landscape (National Institute of Statistics of Rwanda (NISR) 2023).

Figure 1. Administrative map of Musanze District. Source: Author.

2.2 *Methods*

A simple random sampling technique was applied to select the sample size, which guaranteed equal chances of participation in the survey for the whole population within the study area. Sample size, being a phase of research, is most important because of its significant impact on managing the time and finances that must be used in the data collection process (Kothari 2004). A sample size of this research was obtained from about 119,387 households in the Musanze district ((NISR) 2023), and it was calculated with the help of Yamane's formula.

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

From the formula above, n represents the sample size, N represents the number of households, and e represents the sampling error, equivalent to 5%, which meant (0.05) with a significance of 95% confidence level resulting in a sample size of 398 households, which was used in the study. Three hundred ninety-eight questionnaires were distributed among the households in Musanze district. However, 361 questionnaires were retrieved with responses for further data processing and analysis to generate the desired results of this research. The study used both primary and secondary data sources; primary data was collected using 5-point Likert Scale questionnaires and processed using SPSS software version 22. After data processing and analysis, the results were interpreted using Matlab version 2018. The existing literature, such as various books, journals, and office reports relevant to the informal settlement, was used to collect the secondary data. Primary data

3 RESULTS AND DISCUSSION

Figure 2 has three graphs and a pie chart representing various demographic data of the sample size, and these include Gender Distribution as presented on the pie chart shows a nearly even split between males (52%) and females (48%), indicating a balanced gender ratio in the population. The Age Distribution given by the bar graph reveals that the majority of individuals are in the “50 and above” age group (195 individuals), followed by the “30-49” age group (133 individuals), and the least in the “18-29” age group (32 individuals). This suggests an ageing population with many middle-aged and older adults. The Housing Situation comprises renters and property owners, showing more renters, which implies a dynamic or transient population or challenges related to housing affordability. Last but not least, the sample Employment Status given by the bar graph displays almost equal numbers of business owners, employed individuals (who are not business owners), and unemployed individuals. This distribution suggests a diverse economic structure balancing entrepreneurship, employment, and unemployment.

3.1 *Demographic data*

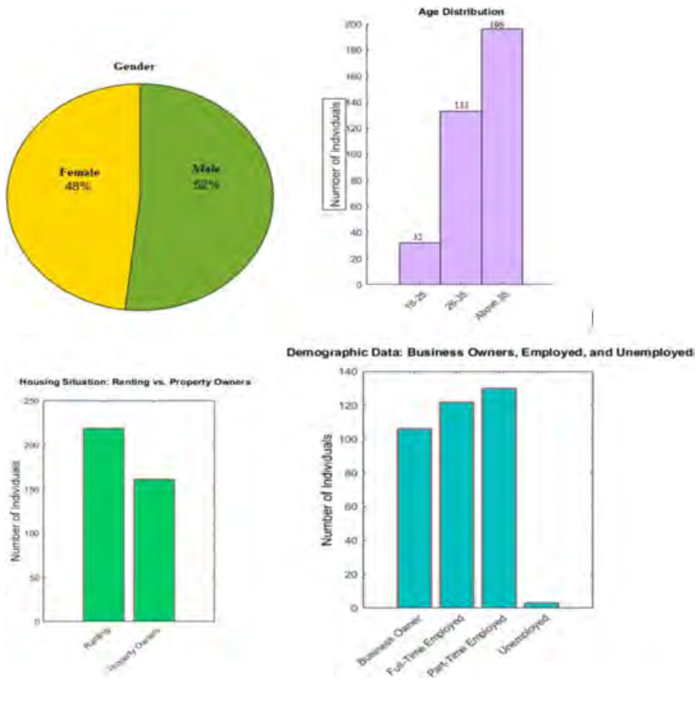

Figure 2. Sample demographics.

3.2 *Features of informal settlement*

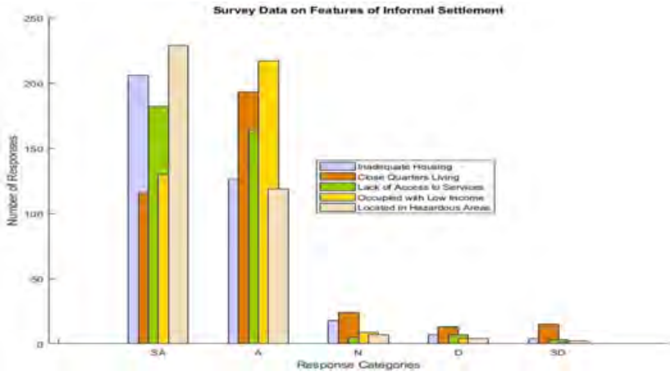

Figure 3. Features of informal settlement.

There are various features of informal settlements found in several areas. The results of this research, presented in Figure 3, reveal significant challenges that highlight the urgent need for sustainable urban development. Most respondents (57.06%) strongly agree that these settlements suffer from inadequate housing, indicating a dire need for improved construction and housing standards. Overcrowding is a prevalent issue, with 53.46% agreeing that families live in cramped conditions, leading to severe health and sanitation problems. Furthermore, 50.42% of respondents strongly agree that there is a lack of access to essential services such as clean water, sanitation, and proper sewage systems, emphasising the necessity for substantial sustainable infrastructure investments and development. The economic aspect is also critical, as 60.11% agree that these areas are predominantly occupied by low-income families, highlighting the need for economic empowerment and affordable housing solutions. Additionally, 63.43% strongly agree that these settlements are in hazardous areas susceptible to natural disasters like floods and landslides, underscoring the importance of incorporating disaster risk reduction in urban planning. These findings collectively stress the need for a holistic and inclusive approach to urban development, focusing on improving housing, infrastructure, and economic conditions to foster resilient and sustainable communities.

3.3 *Factors causing informal settlement*

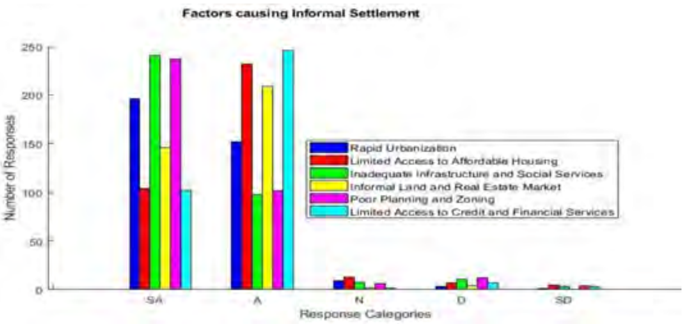

Figure 4. Factors causing informal settlement.

The obtained results, as presented in Figure 4, show that several key factors contribute to informal settlement. A significant portion of respondents (196, 54.29%) strongly agree that rapid urbanisation is a primary cause as cities struggle to keep pace with the influx of people. Additionally,232 respondents, 64.27%, agree that limited access to affordable housing forces many into informal settlements. A striking 66.76% (241 respondents) strongly agree that inadequate infrastructure and social services exacerbate the problem, while 57.89% (209 respondents) identify informal land and real estate markets as contributing factors. Poor planning and implementation of zoning regulations, agreed upon by many respondents, further facilitate the growth of these settlements. Lastly, 246 respondents highlight limited access to credit and financial services as barriers to securing formal housing. Addressing these issues requires comprehensive policy reforms that promote sustainable urban planning, investment in infrastructure, and affordable housing development. Policies should also focus on regulating land markets, enforcing zoning laws, and expanding financial services. Additionally, tackling the impact of climate change is crucial, as informal settlements often lie in vulnerable areas. Integrating these efforts aligns with the Sustainable Development Goals, particularly Goal 11, which aims to make cities inclusive, safe, resilient, and sustainable.

3.4 *Impacts of informal settlement*

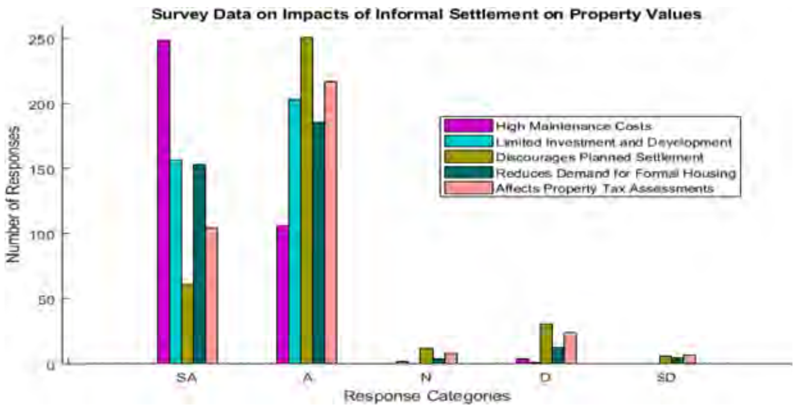

Figure 5. Impacts of informal settlement.

Informal settlement can have significant impacts on the surrounding areas. The results of this research, as presented in Figure 5, show that most respondents (249, 68.98%) strongly agree that these settlements lead to higher maintenance costs for nearby properties. This increased burden can deter property owners and investors from maintaining and improving their assets, negatively affecting overall neighbourhood quality. Furthermore, 203 respondents, 56.23%, agree that informal settlements limit investment and development, as the uncertain and often unregulated environment discourages financial commitments. Additionally, 69.53% of respondents (251) agree that informal settlements discourage planned settlement, disrupting urban planning efforts to create organised and sustainable communities. The study also finds that 51.52% of respondents (186) believe these settlements reduce the demand for formal housing, as potential buyers may perceive the area as less desirable. Lastly, 60.11% of respondents (217) agree that informal settlements affect property tax assessments, leading to potential reductions in local government revenues, which are crucial for funding public services and infrastructure.

To effectively address the challenges posed by informal settlements, practical solutions must be pursued that integrate these communities into the broader urban framework. This entails initiatives like regularising land tenure to grant residents legal ownership, boosting property values and stimulating investment. Moreover, implementing community-driven upgrading projects can enhance infrastructure and services within informal settlements, rendering them more appealing and sustainable. Additionally, fostering public-private partnerships holds promise for mobilising resources to facilitate affordable housing development and infrastructure enhancements. Embracing novel approaches is essential, particularly in light of climate change considerations, given that informal settlements are frequently situated in vulnerable areas. By proactively considering the implications of climate change, policymakers can implement measures to enhance the resilience of informal settlements and safeguard residents against environmental risks.

3 FUTURE PERSPECTIVES

The future perspectives of this research offer a holistic approach towards sustainable development in tackling informal settlements in Musanze District and beyond. By leveraging the study's findings, policymakers can prioritise targeted interventions to formalise informal settlements through land tenure regularisation and legal ownership, fostering community ownership and investment in sustainable infrastructure. Moreover, enhancing essential services such as water, sanitation, and healthcare uplifts living standards and promotes environmental sustainability, mitigating health and ecological risks associated with informal settlements. Inclusive urban planning, driven by collaboration among authorities, communities, and stakeholders, ensures that development initiatives are environmentally conscious and resilient, fostering social cohesion and empowerment while safeguarding natural resources for future generations. Addressing root causes such as poverty and rapid urbanisation through integrated approaches spanning housing, economic, and social policies is crucial for fostering sustainable urban development that advances equity, resilience, and inclusivity in Musanze District and similar contexts worldwide.

4 CONCLUSION

It is worth concluding that informal settlements are not organised and unplanned, making it difficult to provide essential services and hindering sustainable Infrastructure development. Setting aside land suitable for housing is not without its obstacles. The perceived loss of tax revenue relative to other uses in specific communities results from households currently occupying the land not being able to make the land more productive. Upgrading informal settlements and planning is critical to achieving sustainable urban development. The findings of this research underscore a range of challenges prevalent in informal settlements within Musanze District. The factors and challenges highlighted affect the residents' quality of life and extend to broader consequences for surrounding areas, including property devaluation and diminished investment opportunities. Moreover, the research emphasises the imperative for comprehensive and integrated approaches to urban development. It underscores the significance of addressing fundamental factors such as poverty, rapid urbanisation, and the informal land market. Moving forward, practical solutions should prioritise initiatives like regularising land tenure, enhancing infrastructure and services, fostering inclusive urban planning processes, and tackling underlying socio-economic determinants. By embracing these strategies, policymakers can lay the groundwork for a more sustainable, resilient, and inclusive urban future in Musanze District and beyond.

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Theme 2: Infrastructure delivery in developing countries

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Navigating electricity challenges: Spatial and energy planning for sustainable supply in Bolani Road, Soweto Townships

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ABSTRACT: South Africa's heavy reliance on coal-generated electricity, combined with insufficient renewable energy sources, has resulted in a strained energy supply. The struggles of the state-owned electricity producer, Electricity Supply Commission (Eskom), to keep up with the increasing demand have led to frequent planned and unplanned power outages. This study explores the dynamics of energy demand and supply in Soweto's densely populated townships, which are characterised by complex spatial configurations. By using a qualitative approach and non-probability sampling, data was collected from households, businesses, and government participants. Content and discourse analysis revealed that inefficient and ageing infrastructure, including, vandalism, and limited capacity, is the cause of these outages. The government's neglect and Eskom's failure to upgrade and develop infrastructure have worsened the situation. To achieve a sustainable energy supply, spatial and energy planning should prioritise the integration.

Keywords: Energy, Coal, Planning, Outages, Soweto of renewable energy sources

1 INTRODUCTION

The South African electricity supply still relies on unrenewable energy. Whereas continuation of depending on non-renewable resources to generate electricity threatens the government's commitment to the Paris Agreement and Sustainable Development Goal 7, which advocates for green and clean energy provision that is renewable, affordable, and accessible (Merven *et al.* 2021). More than 90% of South African electricity is generated through Coal-Fired Power Plants (CFPPs) that are mostly operated and managed by the state-owned enterprise, Eskom (Zerizghi *et al.* 2022). The CFPPs were built closer to coal mines for convenient transportation; hence, in the past, the South African tariff was among those with the lowest price in the world (Pretorius 2015). However, recently there is insufficient managing of these CFPPs that resulted to the implementation of load-shedding (Du Venage 2020). Since 2007, the country has been experiencing frequent power outages (Nkosi and Dikgang 2018).

Power outages occur in a particular area or region for a certain time when there are electrical faults caused either by a technical disturbance or an intentional shutdown by Eskom within the grid (Ahadu 2019; Falama *et al.* 2022; Ngan 2010). An intentional shutdown happens when the demand outstrips supply, and then a scheduled alternative time shutdown is implemented to save energy or release pressure on the grid to avoid damage to the infrastructure (Arthur *et al.* 2019; Bailey 2022). For example, load-shedding is a planned outage where the end-users are mostly notified in time of when load-shedding will be implemented. There is also an unplanned outage that happens when a single or multiple deficiencies disrupt the normal flow of electricity within the grid (Mahzarnia *et al.* 2020). In other cases, it is related to the damage of infrastructure caused by natural hazards or man-made disaster impacts that trigger technical faults.

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Numerous scholars have explored the distribution of electricity and the issue of power outages that affect communities, businesses, and public institutions within Soweto townships within the City of Johannesburg, in Gauteng province of South Africa (Egan and Wafer 2004; Khumalo and Pretorius 2017; McDonald and Bond 2001). However, there is a lack of studies that focused on the causes of the power outage related to the impact of illegal electricity users found in the backyard units of Soweto. Some studies have investigated the issue of Soweto power outages in relation to the distribution network infrastructure, its reliability and the installation of prepared meter implications based on various household incomes (Khumalo 2016; Mbohwa *et al.* 2019). Instead, these studies have not yet investigated the development and growth of end-users of electricity that are exacerbated by backyard units. The increase in backyard units put a constraint on the existing infrastructure, especially the electricity grid infrastructure that was not designed to accommodate backyard units (Khumalo 2016).

The recurrence of outages hinders the growth of local economic activities and social development (Alhelou *et al.* 2019), particularly in townships. This affects economic productivity by not supporting manufacturing, communication, and service delivery to function efficiently. A reliable and accessible source of electricity contributes to human capital development and a country's economic growth (Ramachandra 2009). Hence, this study's first objective is to investigate the socio-economic challenges faced by end-users along the Bolani Road, this road is the social and economic precinct of Jabulani. The second objective is to explore the strategies employed by the Bolani Road residents, businesses, and institutions as coping mechanisms to support economic activities and sustain livelihoods.

The Integrated Development Plan of the City of Johannesburg (2019: 19) stated that "Provision of basic services to the community of Johannesburg is comparatively high, with the majority of households (both formal and informal) enjoying access to piped water (98.4%), sanitation (95.1%), and electricity (90.8%)". Thus, even the most informal residents in the City of Johannesburg have access to electricity; however, not stated if it is through the Eskom grid or house-supplying backyards. Therefore, this study's third objective is to identify whether the backyard units on Bolani Road, Soweto, are connected legally to the grid or illegally to the main house. This would examine the role played by spatial planning at the study site and the existing energy planning and infrastructure in relation to the recurrence of power outages.

2 CONCEPTUALLY FRAMING SPATIAL AND ENERGY PLANNING

The efficient distribution of energy relies on the integration of spatial and energy planning, which plays a crucial role in understanding supply and demand dynamics. This study's theoretical perspective dissects spatial planning and energy planning, highlighting their importance and the significance of their integration. Planning, in itself, is a vital concept that involves a scientific approach when gathering and analysing information, enabling decision-makers to address the consequences of their actions (Millard-Ball 2013). It is essential in determining aspects that improve electricity accessibility, reliability, and affordability.

Spatial planning, introduced to create comprehensive physical plans, ensures accountability for land cover and land use, shaping urban areas (Hersperger *et al.* 2020; Todes *et al.* 2010). It involves balancing and managing resources or space for a specific population size in a particular area (Alexander 2016; Fuseini and Kemp 2015; Gao and Cai 2017). In South Africa, spatial planning has a complex history, from colonial-era master plans for resource extraction and importation to apartheid-era segregation and allocation of groups in specific spaces (Mokoena *et al.* 2019; Todes *et al.* 2010; Van Wyk and Oranje 2014). In Soweto, spatial planning was used to design housing, such as four-room houses for families and hostels for male workers. After 1994, classical planning approaches were adopted to address past injustices and ensure equal access to basic needs like electricity (Du Plessis and Boonzaaier 2015).

Effective spatial planning is critical for sustaining reliable electricity grids, and decision-makers must prioritise it in energy planning (Asarpota and Nadin 2020; Chirisa *et al.* 2024). By integrating spatial and energy planning, we can develop a comprehensive approach to address the challenges of electricity supply and demand in Soweto. Understanding the patterns and dynamics of housing dispersion, size, and number, as shaped by spatial planning, is crucial for effective energy planning. Energy planning involves developing a comprehensive plan that visualises the possibilities and implications of an energy system using modelling and analysis tools (Sovacool *et al.* 2017). This plan ensures that energy is accessible, affordable, and reliable before implementing an electrification program (Mentis *et al.* 2016). For instance, in South Africa the construction of CFPPs near mines minimised logistics costs, maximised coal availability, and increased electricity supply reliability (Pretorius 2015). This strategic placement demonstrates how energy planning considers economic and environmental dynamics to spatial planning.

Moreover, energy planning prioritises safety by identifying suitable sites for power plants and large electricity grid systems, avoiding catastrophic events in residential areas (Stoeglehner and Abart-Heriszt 2022). For example, Turkey's integration of spatial and energy planning led to the construction of three nuclear plants in a safe location far from residential areas (Ediger *et al.* 2018). In contrast, apartheid government built a CFPP within a residential area of Soweto without considering spatial and energy planning, which was later demolished in the post-apartheid era (Kintzi 2019).

3 METHODOLOGY

This study employed a qualitative approach to explore the lived experiences of end-users along Bolani Road regarding power outages. A phenomenology design was adopted to gather data from participants' experiences and descriptions of outage implications (Whittemore 2014). This design enabled in-depth exploration of the study site and provided a platform for the researcher to gain insight and understanding (Creswell and Creswell 2017). Soweto is an urban periphery area predominantly with black, large and increasing population. Soweto has experienced a rapid and large increase in population, this influx led to a proliferation of informal backyard units, as residents sought alternative accommodation and landlords capitalized on the demand for housing. This rapid population growth has placed significant pressure on the area's energy infrastructure, leading to an increase in the number of end-users of electricity and a rise in illegal connections to the grid.

3.1 *Data collection*

Non-probability sampling was used to select a representative sample from a larger population (Rahman *et al.* 2022). Purposive sampling was applied to select participants based on their position and expertise (Rai and Thapa 2015). This included managers of businesses and institutions, the police station captain, fire station commander, and the ward councillor. Convenience sampling was used to select one available participant per household (Koerber and McMichael 2008). Maximum variation sampling was applied to account for heterogeneous populations and diverse knowledge and expertise (Berndt 2020).

The researchers acted as a human instrument, using observation, photographing, and structured interviews (Disman *et al.* 2017). Structured interviews were conducted to produce unbiased and reliable data (Adhabi and Anozie 2017). Observation and photographing captured events and settings, producing visualisations and reflections (Mphafudi 2014).

3.2 *Data analysis*

Data from recordings, images, and texts were analysed to produce meaningful information. The data were analysed to be theoretically oriented, and the compiled data technics were adopted from Creswell and Poth (2016). Content analysis was used to present trends from analysed text, recordings, and images (Mathenjwa 2010). Discourse data analysis was used to interpret theoretical information and break down non-numeric feedback (Mphafudi 2014). The analysis assisted the researcher in understanding the implications of outages based on participants' experiences, insight, and expertise. The findings provided a comprehensive understanding of the causes, strategies applied, and challenges induced by power outages along Bolani Road.

4 RESULTS AND DISCUSSION

The interview responses from various participants, together with the researcher's observations and photographs taken, indicated that planned or unplanned power outages induce challenges to economic activities and social development on Bolani Road. Based on the managers of the garages and the butchery, the recurring outages put a strain on their businesses, such as additional spending on other sources of energy such as purchasing diesel for their generators. Falentina and Resosudarmo (2019) claimed that businesses cannot operate efficiently when faced with the challenges of power outages; instead, in most cases, it forces businesses to retrench staff. This was one of the challenges the three managers faced. A cut in staff was happening in other shops in the Jabulani Mall that would close when they were experiencing an outage. Furthermore, it meant the closing of many shops causing overcrowding in other shops that use alternative forms of energy.

Most of the unrecognised businesses within households cannot afford to use the alternative energy found in formal businesses. Instead, they rather close businesses for a longer period, which costs them clients, whereas a few of them use smaller generators and gas stoves to keep their businesses operating. The use of gas stoves requires the continuation of gas refilling, which is one of the concerns Geyevu (2022) found to be very expensive for victims of outages. In other words, formal businesses apply the technique Millard-Ball (2013) related to the advantage of planning, which improves the accessibility of energy. In comparison, the scale of implications faced by the big formal and small informal businesses are different because some do and others do not adequately implement the concept of planning.

The institutions also face the challenges of outages, but they have alternative energy sources such as formal businesses that help them manage and provide services to the community due to adequate planning for such events, unlike the community. However, the service provided to the community by the public institutions sometimes gets severely compromised by the challenges induced by outages. For instance, the captain of the police station highlighted that the rate of reporting increases after outages in the surrounding area, and in most cases, it causes ineffective responses to the crime scene because communities affected by outages block the roads. The higher criminal activity rate is one of the findings Geyevu (2022) has noted to be common in townships when there is no electricity. Besides the delay to the crime scene, the community is unable to immediately call for help because the network would be down, which is one of the challenges mentioned by the commander of the fire station.

The network is not the only system that is compromised during an outage; even the security system, which leaves the premises of these places vulnerable to critically disrupting services and compromising sensitive information. Sharma *et al.* (2021) acknowledged that cyber issues such as malware, breaches, and denial of services find it favourable to attack public facility systems when there is an outage. Additionally, there are other challenges facing the community, as demonstrated in Figure 1, apart from the public institution's inability to provide adequate services to the community. For instance, most household participants find it difficult to make food and this affects their daily diet and health because they cannot take their medication without eating first. Thus, because making food is a priority, this distracts children from doing their schoolwork since the process of making fire (burning wood) for cooking requires a lot of time. Awuah *et al.* (2014) argue that lack of resources for improving education, in this case inadequate access to electricity, weaken social development in low- and middle-income countries, especially now that students make use of gadgets that require electricity.

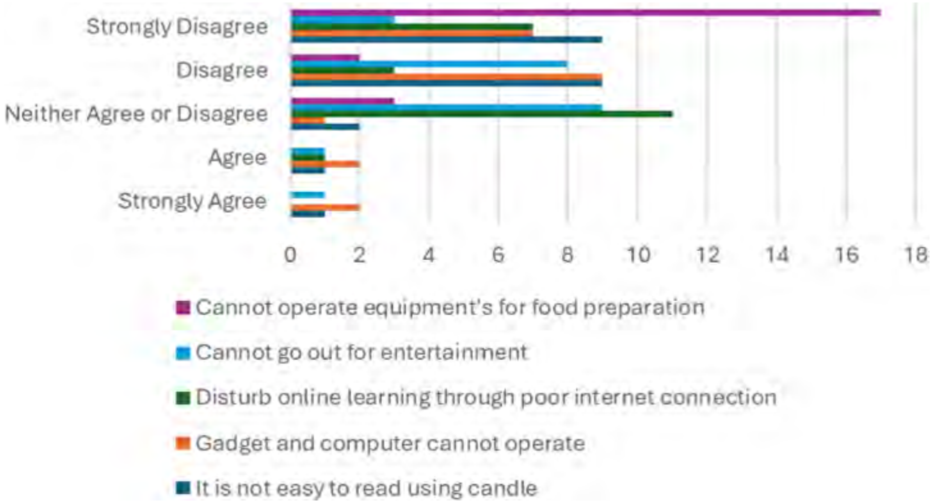

Figure 1. Activities hindered and equipment unable to function during outages (Author 2023).

The spatial and energy planning together with the electricity infrastructure supply within the study site was identified by examining the land zoning and electricity connections of the backyard units. Figure 2 demonstrates the change in land zoning and connection, showing the electricity supplied by the household to the different types of backyard units, which were found to be not connected to the grid but illegally connected from the junction box at the house. Khumalo (2016) found that overload on junctions, transformers, and substations causes outages in Jabulani due to the constraints induced by too many users in an infrastructure that cannot handle the demand. In other words, the various dwelling units shown in Figure 2, are supplied by a junction box designed to only supply the four-room house. Hence, the counsellor stated that he had suggested many times to Eskom that they should exchange and upgrade the infrastructure by replacing the existing supply with a new and higher capacity to meet the demand from many end-users per yard.

Figure 2. Electrification of backyard units (Author 2023).

The researchers observed that most of the junction boxes (Figure 2B) and transformers along the streets (Figure 3) have exploded due to overload. A participant pointed out that transformers and junction boxes explode mostly during the winter when there is a high demand for electricity from the many units per yard. Hence, some of them suggested that the government should at least install solar geysers, to reduce the demand for electricity usage. Having alternative energy sources or switching on certain appliances in a certain time, especially in overcrowded areas, helped with combating the recurrence of outages in Tanzania (Ghanadan 2009). This means that it will help people in those yards with many end-users of electricity if they would alternate with cooking to avoid the demand for electricity that causes explosions, leading to outages. Additionally, building a substation that was proposed by Khumalo's (2016) study, would help with reducing the demand from the Zola substation that supplies the study area. This is another technique of spatial and energy planning integration because that substation would increase the electricity supply for a certain number of users rather than per yard. This means decreasing overloading, automatically limiting explosion of boxes and increasing safety as noted by Stoeglehner and Abart-Heriszt (2022) regarding the integration of spatial and energy planning.

Figure 3. Status of transformers in Soweto (Author 2024).

The energy planning and existing infrastructure of electricity in the present study does not complement or meet the spatial planning and change of land zoning. Hence, some participants claimed that the recurrence of box explosions is associated with a high demand in small infrastructure capacity. But stated that explosions are exacerbated by unqualified technicians who illegally connect and fix boxes when they are tripping. Similar consequences of recurring outages were observed by Braimah and Amponsah (2012), who found that most parts of Ghana's urban settlements experienced outages in relation to the inelastic expansion of urbanisation that causes illegal connections of electricity. Moreover, if a transformer exploded, Pheto (2022) claimed it is easy for criminals to steal and vandalise the infrastructure accessories of the transformers, hence, some communities have safeguarded the boxes.

5 CONCLUSIONS AND RECOMMENDATIONS

There are many socio-economic challenges faced by the end-users of electricity within the area of Bolani Road that are found to be hindering economic and social development. The businesses along Bolani Road are financially challenged, and that plays a role in the increase in the unemployment rate in townships. They suffer financially from frequently purchasing diesel, not having enough staff, and others having a shortage of business hours due to outages. Most informal businesses end up closing for longer periods, and others operate without making a profit because a lot of money is spent on purchasing petrol for generators or refilling gas. Institutions face challenges that cause them to inadequately provide services to the community, even when they can use another energy source to operate. Moreover, the social development of the community is affected by distractions caused by outages in these institutions, resembling poor integration of spatial and energy planning.

Through the challenges that end-users face daily, there are various mechanisms that they employ as strategies to support economic activities and sustain livelihoods. The community use alternative sources for each activity, such as making a fire with wood for cooking. The strategies employed by the business depend on its size and purpose; they use different energy; the majority use generators, while others use gas stoves; and some close the business during the outage. All the institutions have a generator to keep the lights on and power the necessary equipment to provide service.

There is a change in land zoning that has changed the dynamic setting of the household, which does not resemble the known spatial planning. All the backyard units are found to be illegally connected to the main house junction box. This has increased the electricity demand from an infrastructure designed for not for such demand. The illegal connection and lack of proper connection on the grid shows lack of energy planning that has not efficiently advocated the replacement of the ageing and less caring capacity infrastructure. Infrastructure such as junctions and transformers are exploding, causing an unplanned outage due to the many end-users of electricity in a densely populated area that are connected illegally from the main house.

The majority stated that it has to starts with the engagement between all stakeholders, which involves the community, leaders, energy supply and government. The end-users along Bolani Road recommended the introduction of renewable energy sources that would reduce the demand for electricity from the Eskom grid. This can be achieved through government intervention with the installation of solar equipment's in households and public institutions. Additionally, other end-users suggest for government to support Eskom financially for replacement and upgrade of the electricity infrastructure that would allow the backyard units to legally connect sufficiently to the grid.

The influx of people in Soweto township being the fundamental contributor to the intricate spatial configurations that formulate illegal land zoning, with different types of backyard units that need to be controlled. Although these changes are associated with people finding affordable small dwellings within someone's yard, most of them are financially benefiting from these arrangements. This shows a shortage of houses in urban areas of South Africa. Therefore, this calls for policy intervention to revisit the spatial and energy planning policies in urban areas. Additionally, the government needs to provide houses to accommodate the influx of populations in township backyard units.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Drivers of local government service delivery failure in South Africa: Experiences of Matjhabeng local municipality, Freestate province

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ABSTRACT: The local government in South Africa is plagued with many problems, some of these problems are attributable to incompetence of the employees and politicians. In the Freestate province, most of the municipalities have been placed under administration due to unclean audits experiences for some time. This paper investigates the drivers of failure and collapse of service delivery in Matjhabeng local municipality. The study adopted a mixed method approach to review strategic documents. The web of science was used to conduct a systematic search for literature based on co-occurrences and key word analysis. It appears that based on the key themes including local government and service delivery in South Africa only 7 articles were relevant. The results reveal that the local government is faced with service delivery challenges. The paper provides an opportunity for further research and improvements on policy analyses. The paper recommends that the municipalities should implement performance management systems to improve service delivery.

Keywords: VOS viewer, service delivery, Governance, South Africa, bibliometric analysis

1 INTRODUCTION

Mal administration is a common phenomenon in South African Municipalities, this has been a challenge in recent times where most local municipalities are failing to deliver basic services due to unqualified budgets and non-compliance (Sebola 2015). Very few municipalities manage to comply with in South Africa, and this has a huge impact on the fiscal budget allocated to the municipalities, hence these resources are being misused and service delivery is therefore affected (Auditor General 2019). Municipalities also suffer from political factionalism that has been rife in recent years, as a result, new political coalitions were created hence the municipal functionality has been deteriorating (Moyo 2016:8). Moreover, several municipalities around South Africa experience severe challenges of poverty, unemployment, and inequality and this is associated with a high rate of corruption, misuse of funds, and lack of institutional capacity (Mashamaite 2014:234). It is worth noting that this is also true in Matjhabeng Local Municipality. This municipality has been poorly performing over the years, and at some point, it was regarded as the worst run municipality in South Africa, because it owed a total of R3.5 million to both ESKOM and Sedibeng water Board (Cowan 2017). The paper starts by presenting the introduction, it goes to highlight the conceptual synopsis, followed by the research methodology. It then discusses the synthesis of the findings from the bibliometric review and document review. Lastly, the paper presents the conclusion and recommendations.

2 CONCEPTUAL SYNOPSIS

2.1 *Local government*

This is the level of government that is solely responsible for the provision of services at the municipal level, most importantly local government is placed where protests are rife due to

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municipal service delivery. In this sphere of governance, the livelihoods of the people can be made better or worse (Botes *et al.* 1996:223). Ultimately, Cloete (2012:17) posits that local government is the administration and governance of local people to control and promote what the local communities do. For Venter and Landsberg (2011:130) this sphere of government was established to bring governance and the delivery of services closer to the people and it is therefore considered to be a second or third sphere of governance globally. However, for Heymans and Totemeyer (1988:2) local government is a decentralised institution that has certain power attached to it with an identifiable geographical boundary in a country. Most importantly, local government is essential in assisting the main government to achieve its goals because it is the local government that carries the goals of the government and their achievement is dependent on the capacity of the local government (Botes *et al.* 1996:224).

2.2 *Service delivery*

Beyers (2016:169) indicates that service delivery is about the provision of benefits and public facilities, these could be both intangible services and tangible public goods. To maintain the quality of life of the local people it is equally important to provide basic social, education, infrastructure, and health services in small towns and rural areas (Venter 2010). Adding to this Mafunisa (2008) echoes that the constitution of South Africa mandates the municipalities to provide the local communities with basic services, and municipalities should encourage the development of residents. In contrast, Chin, and Chan (2004:210) suggest that the local government's ability to improve the delivery of services can be efficient if the government of the day works on reducing the problems that proactively prohibit service delivery. It is the government's responsibility to ensure that its policies are effectively implemented by the municipalities. Service delivery challenges in South African municipalities are increasing at a high rate, however, it is important to note that these challenges are unique to each municipality (Edwards 2015:25). Beyers (2016:169) asserts that many municipalities are failing to maintain and operate infrastructure efficiently and effectively, and these challenges extend to overall service provision, inefficient procurement procedures, procedures in recruiting new staff members and silo working between the business community and the municipality (Matos *et al.* 2012:329). The situation in Matjhabeng is worse as several protests relating to poor service delivery have been observed.

3 MATERIALS AND METHODS

This research paper is based on a mixed method approach, to gain access to data, relevant strategic documents and reports were reviewed including the Matjhabeng Local Municipality 2022/23 Integrated Development Plan, Auditor General report. Therefore, the place of interest is Matjhabeng Local Municipality which is under the Lejweleputswa District Municipality in the Free State.

A bibliometric analysis of studies on local government and service delivery was conducted, and the analysis of the literature was done quantitatively (Van Nunen *et al.* 2017). The analysis focused on co-occurrences and country of publications as well as citations of the literature. In this paper, Vosviewer version 1.6.20 was used to map the literature extracted from Web of Science database data (Donthu *et al.* 2021:285). The screening of the articles was based on the PRISMA protocols. The key analysis was based on co-occurrences, country, and citation. The figure presents the procedure followed in conducting the bibliometric review.

3.1 *Procedure*

The data relating to the study was reviewed, the year of publication was not specified hence all papers were suitable for review. The following key words were used in web of science search engine:

a) "Local government" AND "Service delivery"
b) "Local government" AND "Service delivery" AND "South Africa"

See Table 1. For criteria for inclusion in this paper.

Table 1. Selection criteria.

Inclusion	Exclusion
All articles with studies on local government and service delivery globally and South Africa Published in English	Publications outside local government and service delivery. Non-English publications. Unpublished thesis and newspapers

The literature search followed the screening of article titles and abstracts to check their suitability for this study. The process was guided using PRISMA, which is generally used to scan through the literature to find answers to an identified research question (Selcuk 2019). see for example Figure 1.

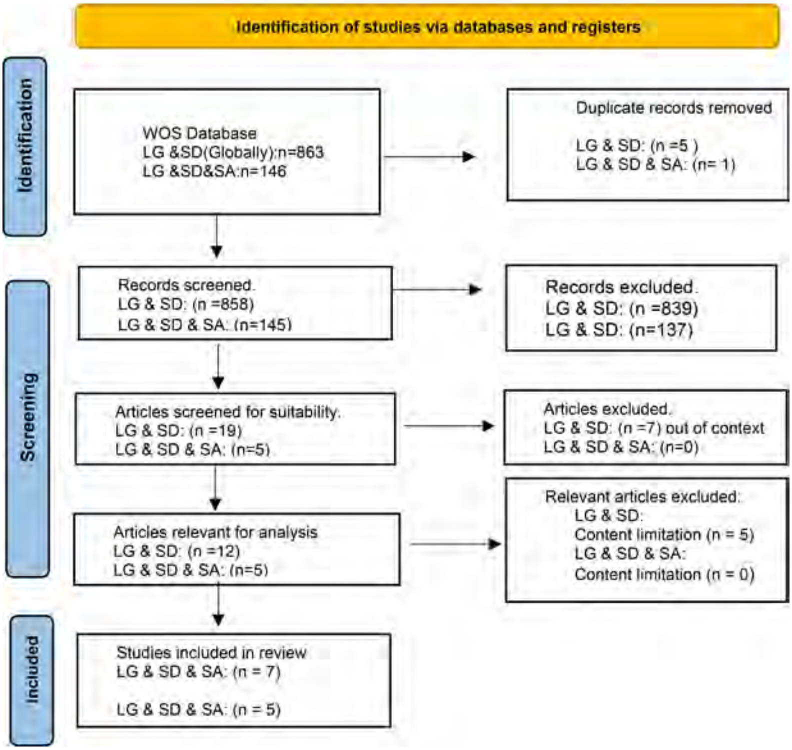

Figure 1. Prisma protocol (Source: Authors: 2024).

The search in WOS as shown in Figure 1, Identified a total of 863 articles on the terms "Local government" AND "Service Delivery" globally. Of these 5 articles were found to be duplicates and were excluded which left the search with 858 articles to be used for the first analysis. After further scrutiny of the abstracts and paper titles 839 articles were excluded on the basis that they did not entirely fit in the scope of the research, 19 articles were then further scrutinized for eligibility and 7 were excluded because they were out of context, as they emphasised on "local governance". After using the PRISMA protocols, only 12 articles were then selected for the review in this study. For terms "Local government" AND "Service delivery" AND "South Africa" a total of 146 articles in the WOS database we identified, and 1 article was found to be a duplicate and it was removed which left 145 articles for the first analysis. Following further scrutiny 137 articles were excluded because they do not entirely fit in the research.5 articles were further reviewed for eligibility, and they were all qualified as relevant in this paper through PRISMA protocols.

Table 2. Description of the symbols used in the bibliometric analysis.

Symbol	Description
clusters	The circles in the network representing the items
Items	Items used for analysis in this study
Links	Relationship between items such as co-occurrence and country
Cluster	Agglomeration of items identified by colours

It is important to note that the VOS viewer software presents visuals for the reviewed literature including the themes, research focus, and trends (Zhang and Quoquabl 2021). Bubbles shown in the network diagram are interpreted as follows; the larger the bubble the higher the number of articles associated with local government and service delivery. The distance between the bubbles indicates the relationship between the items. Yu and He (2020) assert that when the distance is shorter the relationship between the items is strong. Notably, the different colors of the bubbles and links represent the clusters.

2 RESULTS AND DISCUSSION ON BIBLIOMETRIC ANALYSIS OF LOCAL GOVERNMENT AND SERVICE DELIVERY GLOBALLY AND IN SOUTH AFRICA

A total of 7 articles were reviewed in this paper, these articles were selected from the 863 articles that were initially identified through the Web of Science. Hence, Lewis (2017) studied the proliferation of local government in improving service delivery in Indonesia, and this study discovered that the creation of new local governments has negatively impacted access to water and sanitation. In their study, Muyomba-Tamale and Cunningham (2017) examined the Ugandan scorecard initiative for local governments as an accountability initiative, while the study did not outline the drivers of local government failure in service delivery. It is apparent from the results that the scorecard initiative has yielded some positive results. Also, Abdul-Khalid (2010) studied the improvement of service delivery in Malaysia, the study discusses the performance management systems undertaken to improve service delivery. The study discovered that the performance management systems have improved accountability at local councils. Consequently, Schoute, Gradus, and Budding (2021) investigated the influence of political, financial, and service features on the four modes of service delivery being "in-house, inter-municipal cooperation, municipality-owned firm and private firm" Dutch local government. The study found that political fragmentation affects service delivery.

In the case of South Africa, Ramutsheli and Van Rensburg (2015) investigated the drivers of the local government's failure to achieve the service delivery objectives. This research is relevant in this study because it discovered the root causes of the local government's failure which include a shortage of human resources, lack of skills, and unethical structural culture or lack of performance management systems. This is echoed by Khale and Worku (2013) who examined the factors that affect service delivery in Gauteng and Northwest municipalities, the study revealed that local municipalities are allocated sufficient resources, however, they are not effectively used due to lack of accountability and skills. Interestingly, Schoeman and Chakwizira (2023) provided a different view when they evaluated the "performance management tool for service delivery in local government" The study revealed that there are persisting gaps in service delivery in local governments, there is performance gap because of the inadequate policy frameworks relevant to the developing countries. There is also a mismatch of policies and regulations with the local needs, and these are some of the hurdles that need to be addressed to improve service delivery.

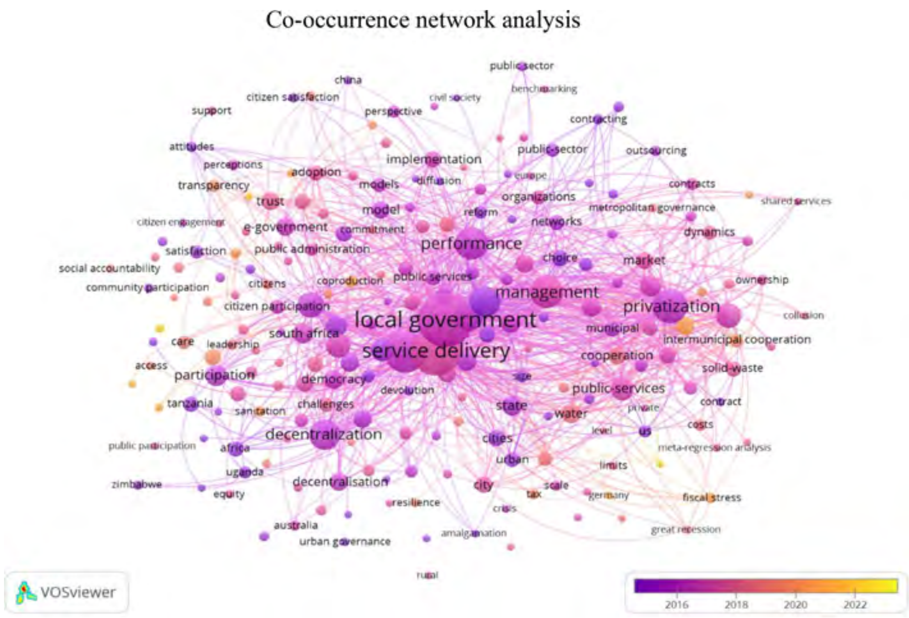

Figure 2. Co-occurrence network analysis (Source: Authors 2024).

A co-occurrence network analysis was performed representing 4 colours deep purple, light purple, orange, and yellow colour. Within the light cluster, the dominant items are Local government, service delivery, performance, management, and decentralisation. The dark purple clusters represent countries and key words such as citizen satisfaction, choice, contracting which are not part of this paper. Orange bubbles contain words such as transparency, inter-municipal cooperation, and water. Followed yellow bubbles contain key words such as fiscal stress and coproductions. The analysis indicates that Local government, service delivery, decentralisation and performance are the most studied keywords especially between 2016 and 2018. The light and dark purple clusters seem to tie closer to each other, this can be attributed to the fact that the performance of local governments has a close impact on service delivery, same as decentralisation.

3 STRATEGIC DOCUMENTS ANALYSIS

3.1 *Provisions from Matjhabeng local municipality 2022/23 IDP*

The provision of water, according to the Matjhabeng 2022/23 IDP is done by the Sedibeng water. However, the greatest challenge that the municipality is facing is the water disruptions caused by increasing steel pipe theft (Matjhabeng Local Municipality 2022:18). This has an implication on the budget of the municipality because it increases the expenditure of the municipality. After all, they spend more on repairs and maintenance. Regarding sanitation, it is reported in the IDP that the sewer reticulation system is more than 40 years old, hence on several occasions, the pipes burst therefore because of this aging infrastructure the municipality usually experiences blockages and sewage spillage. The municipality is contemplating declaring this as a national disaster so that they can get assistance from the national government (Matjhabeng Local Municipality 2022:18).

4 SYNTHESIS OF THE FINDINGS

In this study, a bibliometric analysis indicated that most studies have focused on local government and service delivery challenges globally and in South Africa. The analysis revealed that there is political and financial challenges on service delivery, according to McKinley (2011:2) financial management should be addressed in these municipalities by strengthening skills acquisition processes. In addition, Pretorius (2017:127) postulates that the political infighting within the ruling party is part of the problem, the leaders tend to focus on their battles and neglect their responsibilities regarding service delivery, this is evident in Matjhabeng local municipality. Gordhan (2014:5) reiterated that most of the municipal personnel are unskilled and lack institutional capacity, hence they fail to promote adequate and efficient service delivery. This is echoed by Mbandlwa, *et al* (2020:1644) that there is a lack of accountability and acceptance of bribes which affects service delivery in local government. On the issue of the mismatch of the policy frameworks in local government as indicated in the analysis. This concern was outlined by Pretorius (2017) who outlined that administrative accountability is related to the employees of the municipality, hence their behaviors have a bearing on the set goals. These employees still must align with the legislative framework which stipulates how they will be held accountable and how their work will be evaluated. Consequently. Modiba (2022) asserts that there have been service delivery complaints in Matjhabeng, with the community alluding that the municipality has been non-responsive to their complaints. The municipality officials always cite that they are waiting for the budget. This then means that the municipality is struggling to sustain itself, this could be associated with the lack of capacity to deal with technical challenges.

The Matjhabeng local municipality 2022/2023 IDP states that the municipality has aging electricity, road, and sewer infrastructure hence sewer spillages are all over (Matjhabeng local municipality 2022:25). Cowan (2017) reiterates that this municipality is one of the worst run municipalities in South Africa, citing that in some of the main suburbs of Welkom people navigate through sewage spillages. Therefore, this implies that the municipality cannot deal with this problem, hence the call for the national government to intervene. It is important to note that around 11% of the households in Matjhabeng are still using bucket toilets, which have long been declared to be unsustainable. With only 24.7% of the population using flush toilets and 47.1% using pit toilets and having access only to communal taps, this reflects how worse the situation is in this municipality. The results provide evidence that the municipality's expenditure is exacerbated by the maintenance of these roads as they require a lot of money. Just as the road's infrastructure, the municipality is facing the same challenge of aging electricity infrastructure, also there is an increasing rate of vandalism on electricity infrastructure with the municipality stating that these acts are done by the illegal miners. And these have a negative impact on service delivery within the municipality.

The analysis indicates the key areas where research focuses on drivers of local government failure in service delivery failure, the key areas revealed are performance, service delivery, decentralisation, and local government. Indicating that these are the most researched words as indicated in Figure 2. However, the analysis revealed that most research does not investigate and explicitly outline the local government failure. And this provides an opportunity for further research.

5 CONCLUSION AND RECOMMENDATIONS

This research paper's argument resonates on what are the drivers of local government service delivery failure. This study responds to a wide range of questions during the period in which several municipalities are being placed under government administration because they are on the brink of collapse. In terms of the conceptual framework, the paper covered local government and service delivery as the key concepts. The paper adopted a bibliometric review and strategic document analysis, and the results revealed that Local government is faced with challenges including financial, political, and lack of human resources for efficient service delivery. Ultimately, the paper concludes that there are common challenges faced by local governments for efficient service delivery as revealed by the bibliometric analyses. While the challenges are similar, some local governments have implemented performance management systems to monitor their performance. The IDP revealed that Matjhabeng's local municipality is not immune to these challenges. To address the outlined challenges to service delivery, the local government must implement performance management systems where municipal employees will be held accountable for lack of improvement in service delivery. Municipalities should account for careless spending. It is important to note that regular maintenance of infrastructure should be done by the local municipalities, to improve the efficiency of services including water and electricity and aging sewer infrastructure.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Telecommunication infrastructure development and environmental social governance nexus: Experiences of mining host communities in South Africa

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ABSTRACT: Infrastructure development plays a substantial role in communities' societal and economic development. Practical strategies that facilitate the planning and implementation of infrastructure projects are imperative for societal impact. While there has been increasing acknowledgment of the positive influence of environmental social governance efforts on community development, there is still a need for transparent processes of adopting the concept to realize sustainable telecommunication infrastructure development, particularly in host mining communities. In the case of Aggeneys, Pella and Pofadder the launch of the community Wi-Fi and extension of radio signal has fortified sustainable practices amongst the community and lessened the digital divide existing in the community This paper relies on empirical data, document, and scoping review. The empirical data collected was analyzed using the SPSS software. The work culminates into sustainable telecommunication infrastructure coined in the development and implementation of the environmental social governance nexus through policy change.

Keywords: policy, environmental, social governance, sustainable development, infrastructure, framework

1 INTRODUCTION

The world has transitioned into a digitally enabled world. Technological progress and implementation have played a role in the notion of sustainable development globally through the deployment of telecommunication infrastructure (Calabrese *et al.* 2023; Mohsin *et al.* 2022). Research suggests that the presence of telecommunication infrastructure is likely to improve livelihoods (Emeana 2020). Scholars Kopina and Schopp have put forth that sustainable development ought to improve the next generations' lives (Kopnina and Schopp *et al.* 2020). Contrary to the above, a vast range of literature has highlighted questions on the impact and the extent of sustainability in telecommunication infrastructure development (Harris 2016; Qureshi 2015). Digital technologies, such as blockchain, artificial intelligence, satellites, and the internet, have evolved over time and have since been adopted as developmental tools (Asenso-Okyere *et al.* 2012; Kaware and Sain 2015).

Access to telecommunication infrastructure such as Wi-Fi has proved to enhance government service delivery; therefore, an enhancement in the quality of life of municipal residents (Methane *et al.* 2024). Digital technology strategies and processes have served as the gateway to sustainable communities through the betterment of livelihoods (Mondini 2019; Zielinska-Dabkowska & Bobkowska 2022; Zvolska *et al.* 2019). However, though digital

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technologies have improved service delivery, businesses, and societies technological advancements have also negatively impacted societies through polarization and the evident digital divide between developing and developed countries. Technological advances have brought about increased unemployment due to automation, increased energy consumption, and electronic waste (United Nations 2019; Vetora *et al.* 2023). There are related studies in South Africa. However, the relationship between environmental social governance frameworks and its influence towards carving sustainable communities has yet to be explored. Therefore, a new ecosystem of sustainable development in telecommunication should be adopted by developing environmental and social governance frameworks.

2 BACKGROUND

The environmental social governance principle was proposed in 2004 and has since been popular amongst developed countries. It has recently gained traction in developing countries (Li *et al.* 2021). The principle of environmental social governance originates from the principles of responsible investment, which guides investment decisions and business strategies to ensure the sustainable development of communities, (United Nations Principles of Responsible Investment 2024). Mining corporations in South Africa have since adopted these principles as mandated by the Minerals and Petroleum Resources Development Act (MPRDA) through corporate social responsibility. However, the effective implementation of corporate social responsibility has proven to be a challenge, and as a result, poor corporate social responsibility implementation has manifested in frequent community unrest. (Vhubunu 2021).

The study hypothesizes that an environmental social governance framework may influence sustainable telecommunication infrastructure development through corporate social responsibility efforts. This paper is a case study on the Aggeneys, Pella, and Pofadder mining communities in the Northern Cape province of South Africa. The Northern Cape is the largest province spatially in the country, with an area coverage of 372 889km^2. The nucleus of the study is the Khai-Ma municipality, Northern Cape Province, South Africa. The study takes place in three semi-urban towns, namely Aggeneys, Pella, and Pofadder. According to the results of the 2022 national census from StatsSA (2022), the current total population in the Northern Cape province is 1355 945, showcasing a15.49% growth from the census 2011 results of a population of 1 145 861; the Khai-Ma local municipality only contributes 0,63% towards the provincial total population.

3 CONCEPTUAL FRAMEWORK

Environmental social governance (ESG) can be defined as the criteria by which organizations measure their corporate sustainability and ethical performance, which informs business strategies and processes (Arora and Sharma 2022). Corporations embrace the philosophy of ESG to observe and supervise the effects of business activities such as corporate social responsibility (CSR) implementation on the society (Viranda *et al.* 2020); Merli and Preziosi 2018). The concept of CSR, as defined by Aguinis (2011), refers to the 'context-specific' organizational actions and policies that consider stakeholders' expectations, concurrently producing value for its stakeholders to achieve a triple bottom line performance, which is social, economic, and environmental, (Bellandi 2023; Setiani *et al.* 2023). Digital technology solutions have been used to become a primary tool in achieving sustainable development, and therefore, the adoption of the environmental social governance nexus is key to the governance of telecommunication infrastructure development (Vetrova *et al.* 2023).

Environmental social governance frameworks are deployed as a governance tool for the betterment of communities' livelihoods through sustainable development. With the growing need for digital technologies, telecommunication infrastructure development has since been vastly deployed through corporate social responsibility project implementation as efforts toward the development of smart cities (Methane and Gumbo 2024). Scholars Nikitaeva (2023) and Vitrova (2023) argue that telecommunication strategies and processes deployed and adopted in the quest for smart cities have succeeded. The above statement is backed by empirical data suggesting that urban challenges have been successfully addressed by implementing digital technologies such as Wi-Fi in communities (Onyango *et al.* 2021). Several frameworks have been developed to evaluate how sustainable telecommunication, information, and communication technologies interventions can be used for the betterment of livelihoods and governance purposes (Emeana *et al.* 2020).

4 THEORETICAL FRAMEWORK

This paper applies the social systems theory and the resilience theory to identify the gaps in knowledge and increase research efficiency toward telecommunication infrastructure development and the nexus of environmental and social governance. The social systems theory describes organizations and communities as closed social systems self-created by organizational processes (Stewman 1975). Luhmann (1984) emphasizes that the pressure of expectations created by organizations of communities are large building blocks of the closed systems formed. At the foundational levels, they are not open to their environment; this includes affiliates of the societies in making choices of what would be ideal and beneficial to them as the system is closed and does not promote collaboration; social systems are not entirely translucent and easily manageable. The moving pieces of social systems are communications, actions, and decisions, (Mayrhofr 2004).

In a social system setting, various approaches are followed to promote conformance and cooperation of the greater community, such as the structural and communication approaches (Dawes 1980; Messick and Brewer 1983; Van Lange *et al.* 1992). Following the structural approach, sanctions do not promote sustainability as this influence's mandatory conformance, which is involuntary actions against human rights, promotes rebellious behaviors when these are uplifted (Mulder *et al.* 2006; Tyler 2010). The communication approach is more sustainable, as this voluntary conformance significantly promotes cooperation. This is because communication occurs between two or more parties, which encourages trust and commitment between all the parties involved. (Dawes *et al.* 1990; Orbell *et al.* 1988).

5 METHODOLOGY

The paper adopts a case study research design and a mixed method research approach. The author adopted the case study research design to generate a thorough understanding of the complexity of telecommunication infrastructure development and the nexus of environmental social governance in the Aggeneys, Pella, and Pofadder mining host communities. The mixed method research approach was adopted to develop an objective approach to data analysis (Pawar 2020). The study adopts a scoping review methodology, which includes a thorough document review and analysis of the processes and strategies of telecommunication implementation in a mining host community in the pursuit of sustainable communities. The document scoping review included the collection of the social and labor plan, which is a legislative document required by South Africa's Department of Mineral Resources and Energy with the primary goal of improving socio-economic matters in mining host communities and transforming the mining industry.

Furthermore, the document scoping included the mineral rights holder's sustainability framework, the integrated development plan of the Khai-Ma municipality, and the South Africa Department of Communication and Digital Technologies policy on rapid deployment of networks and facilities as secondary sources. Once the documents had been acquired, the researchers thoroughly analyzed and evaluated them through a literature review and noted the processes and strategies adopted by various stakeholders to achieve sustainable infrastructure development relating to telecommunication development. Therefore, the document review deployed an exploratory qualitative research approach. Moreover, 140 research questionnaires were developed by the researcher to assess infrastructure development in the Aggeneys, Pella, and Pofadder host mining communities. The questionnaires were digitally distributed to the communities through google Forms, and the results were processed through the statistical package for social sciences Findings and discussions.

6 PRESENTATION AND DISCUSSION OF RESULTS

6.1 *Telecommunication infrastructure*

The South African national policy on rapid deployment of networks and facilities of 2023 was developed from the national integrated ICT Policy of 2016. The purpose was to ramp up national coverage of broadband infrastructure, as this is necessary for creating a digital society and economy and encouraging socio-economic development. The policy aims to develop and provide a process for deploying an electronic communication network. The objective is to enable the rapid deployment of broadband infrastructure in an efficient, cost-effective, and environmentally responsible manner (Government Gazette 2023). Technological policy development is informed by the everyday movement of information in urban areas compared to rural and local communities (Aruleba and Jere 2022). Results from the South African 2011 census showed a digital divide in the Khai-ma municipality, showing non-digital communities in the Aggeneys, Pella, and Pofadder mining host communities.

The study showed that approximately 77.8 % of the Khai-Ma municipality residents needed access to the internet, either through cell phones, at home, or work. That is a concerning reality that is enabling a digital divide in society. As shown in Figure 1 below, the data illustrates that the communities are hindered by the possibility of skills development and educational improvement because of no access to the Internet. These 2011 census statistics have influenced stakeholders such as the national government to develop policies such as the South African national policy on rapid deployment of networks and facilities to facilitate digital societies and communities. Affiliated stakeholders needed to take responsibility and accountability for their roles and put more effort into ensuring the development of sustainable telecommunication infrastructure is deployed through corporate social responsibility efforts guided by environmental social governance efforts.

Table 1. Access to the Internet for the Khai-Ma local municipality according to Statistics South Africa (2011).

Access to the internet	Khai-ma local municipality percentage	Namaqua district municipality percentage
Access from home	3,5%	5,5%
Access from the cellphone	13%	14,3%
Access from work	3,8%	4%
Access from elsewhere	1,9%	1,9%
No access	77,8%	74,3%

As such, through corporate social responsibility interventions, telecommunication infrastructure was installed in 2020, allowing the Aggeneys, Pella, and Pofadder mining communities to access Wi-Fi and promote digital communities, granting them 500 MB of data per person each week. This illustrates the role played by the stakeholders operating in the Khai-ma municipality in addressing community challenges to align individual policies to the national mandate.

The digital divide often exists due to rural communities' need for more material and infrastructure, even during the digital age (Aruleba and Jere 2022; Kilpelainen and Marjaana 2014). Therefore, with the presence of the telecommunications infrastructure in the Aggeneys, Pella, and Pofadder mining host communities, the residents are responsible for carving and improving their small businesses and seeking and creating economic opportunities to enable digital communities and a digital economy.

6.2 *Indicators of sustainable communities*

According to the United Nations Development Program, the increased use of technology facilitates continuous improvement and improves the delivery of basic services in communities (Corrigan 2020; Oyedemi and Mogano 2018). In the case of South Africa, technological advancements were skewed as a result of apartheid as historic ICT policies did not advocate for equal technological advances, however, this has since changed post-democracy, and policies such as the national policy on rapid deployment of networks and facilities have been developed to ensure fair distribution. Although policy advancements have been made, the digital divide still exist in residents of previously disadvantaged communities, as seen in the Aggeneys, Pella, and Pofadder communities. The responses from the participants of the study illustrate that innovation and infrastructure is not exemplary in achieving and carving sustainable communities .The respondents regarded clean water and sanitation as the most critical indicator of a sustainable community at 70.7%, followed by access to adequate healthcare at 60.7%, no poverty and zero hunger at 50%, decent work, and economic growth at 47.9%, safe communities at 31.4%, affordable and clean energy at 15.7% and finally innovation and infrastructure at 12.1%.

Table 2. The state of innovation and infrastructure in the Aggeneys, Pella, and Pofadder host communities.

Indicators of sustainable communities	Responses
Safe Communities	31.4%
Clean water and sanitation	70.7%
Access to adequate healthcare facilities and wellbeing	60.7%
No poverty and zero hunger	50%
Decent work and economic growth	47.9%
Affordable and clean energy	15.7%
Innovation and Infrastructure	12.1%

As detailed above and shown in Figure 2 below, the results illustrate that the Aggeneys, Pella, and Pofadder mine host communities do not rate innovation and infrastructure as an indicator of sustainable communities. Therefore, the above statement suggests that despite the availability of telecommunication infrastructure, the digital divide is likely to remain prevalent in the communities. This demonstrates the need for more education towards informing communities on the importance of technological advances; various strategies and processes must be developed to educate communities on the global market and the digital changes that exist as enablers of economic growth.

According to Urvashi *et al.* (2017), two problems stir and cause the digital divide: poor communities and lack of training in communities. The latter applies to the Aggeneys, Pella, and Pofadder communities as there is no limitation to digital infrastructure. However, the limited access to digital technology training has resulted in uninformed internet consumption and low digital skills realization. Therefore, training will present the roles and responsibilities that each community member plays towards realizing the dream of digital communities and how that may positively impact their healthcare systems, educational systems, and various other essential services in a digital economy.

8 THE PRESENCE OF TELECOMMUNICATION INFRASTRUCTURE DEVELOPMENT IN THE AGGENEYS, PELLA, AND POFADDER MINING COMMUNITIES

Infrastructure development is required for economic and societal development (Panday and Sto 2022). Therefore, infrastructure facilitates sustainable development by addressing various sustainability challenges societies face. However, the presence of infrastructure inequality may affect the impact and progress towards carving sustainable communities (Seto 2017; Thacker *et al.* 2019; United Nations 2020)The results show that 36.4% of the time, the residents of the Aggeneys, Pella, and Pofadder host communities were aware of potential infrastructure developments that were happening in their communities, 35.7 % of the participants argued that only sometimes were they aware of new potential developments and 27.1% responded that they are not aware of potential developments and 0,8% said they have never been aware of new and potential infrastructure. This shows a communication gap, disjuncture, and infrastructure inequalities that may affect carving sustainable infrastructure. Though initiatives might be in place, the Aggeneys, Pella, and Pofadder communities feel they need to be fully part of the process, showing inequalities; therefore, this illustrates a gap in infrastructure development and implementation, ultimately impacting communities.

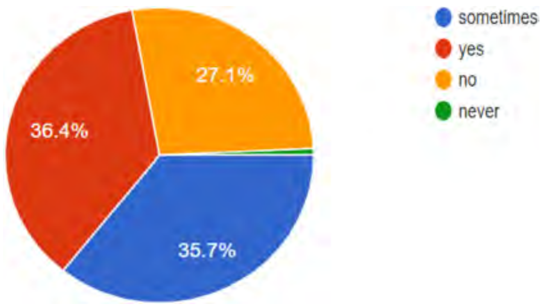

Figure 1. Infrastructure awareness in the Aggeneys, Pella, and Pofadder host communities.

The absence of digital technologies has been the basis of the digital divide in the economic and social sphere globally, in developed and developing countries (Aruleba and Jere 2022). Aggeneys, Pella, and Pofadder's case has been similar to the global state of affairs. Telecommunication infrastructure was initially developed in 2018, with phase one covering Aggeneys, Pella, and Pofadder regions, and it was in the year 2022 that the telecommunication infrastructure was extended to other regions of the Khai-ma municipality, Onseepkaans, and Witbank, as displayed in Figure 2 below.

The installed telecommunication provides the communities with 500 MB per week, and upon discussions with community members, they have attested that access to the internet is a valuable tool for education and of benefit to small businesses in the region, as previously discussed in the access to the internet section above. To expand communication into the Khai-Ma region, the mineral rights holder had committed to extending telecommunication infrastructure for the local radio to reach the Aggeneys, Pella, and Pofadder mining host communities by 2022. However, the local radio signal only went live in 2024 in the area. The absence of radio communication in the Aggeneys, Pella, and Pofadder regions suggests socio-economic exclusion for the communities.

The inequality of internet and communication access through digital technologies such as radios is common in developing countries. However, scholars like Arunachalam (2004) have argued that telecommunication infrastructure development may aid poverty reduction. The acknowledgment of improvement of easy accessibility from small businesses in the Aggeneys, Pella, and Pofadder regions demonstrates the effect of telecommunication infrastructure development on socio-economic development. (Mora-Rivera and Garcia-Mora 2021)

Figure 2. Telecommunication infrastructure development in the Aggeneys, Pella, and Pofadder host communities (Vedanta Zinc International 2024).

7 DISCUSSIONS AND LESSONS LEARNED ON ESG

Government and private corporations commonly reach a consensus, yielding positive implementation results (Ansell & Watt & Watt 2007; Emerson *et al.* 2011; Guo *et al.* 2024; Van der Watt 2020). Therefore, effective telecommunication infrastructure development can only exist with collaborative governance of institutes and stakeholders. The mining charter of South Africa, as gazetted in 2018, advocates for collaborative governance as it mandates the mineral right holder to consult with relevant mine communities, traditional authorities, and the mine communities in which they operate to collaboratively identify developmental areas and priorities the area, (Mining Charter 2018). The debate around collaborative governance has grown to be a robust one; scholars argue that the notion of collaborative governance has been an emergency reaction to failed project implementations, and contrarily so, others argue that collaborative governance stems from the growth in knowledge, increased institutes have become interdependent and more complex. However, environmental social governance strategies and processes have developed a contingency approach towards collaborative governance.

The use of environmental social governance is not a mandatory practice, though it serves as a governance framework; despite the growth in the adoption of environmental social governance nexus, various organizations across the globe do not adopt the practice (Conradie *et al.* 2020; Cho *et al.* 2014). Good governance and stewardship are realized by creating shared value for stakeholders (Emeka-Okoli *et al.* 2024; Nashchekina *et al.* 2020). Therefore, the adoption of the environmental social governance framework in Aggeneys, Pella, and Pofadder has seen socio-economic benefits for the community. For instance, the initial plan for the extension of the radio signal was in 2022; however, the adoption of environmental social governance saw the effective and successful implementation of the telecommunication infrastructure in 2024. Therefore, the mineral rights holder's adoption of environmental and social governance shows commitment and determination toward mitigating sustainability risks, including the community's digital divide and inequality (Boiral *et al.* 2019; Perego and Kolk 2012). It is clear as one inspects the organization's strategy in correlation with the data that there has been groundwork conducted, such as a materiality assessment, as the sustainability strategy is already addressing the issues arising in the community.

8 CONCLUSION AND RECOMMENDATIONS

The United Nations' sustainable development goals advocate for improving livelihoods by creating sustainable cities and communities across the globe to ensure decent economic growth. The study finds that the residents feel as though they are sometimes aware of the developments in the Aggeneys Pella and Pofadder communities, but sometimes they are not. This, as mentioned above, creates a gap illustrating that there needs to be a clearer understanding of the roles and responsibilities that stakeholders, as well as the residents of the Aggeneys, Pella, and Pofadder communities, carry. The lack of a clear understanding of roles and responsibilities may lead to telecommunication infrastructure development failing and not being received well by the communities as there has been a communication gap. Therefore, an environmental-social governance framework nexus should be adopted to frame and structure telecommunication infrastructure project implementation by carving sustainable infrastructure. Developing telecommunications infrastructure in the Aggeneys, Pella, and Pofadder communities has bridged the gap, as the 2011 Statistics South Africa report highlighted. However, the study's results illustrated that 12.7% of the study participants rated innovation and infrastructure development as critical to the quality of life and livelihoods; again, this illustrates the gap in communication as the stakeholders and the community members need to be aligned. Therefore, the study recommends that although development is pivotal and necessary, the gap in communication of roles and responsibilities delays the development of sustainable cities and communities; therefore, environmental social governance frameworks should be developed and adopted, which will inform infrastructure development and carve sustainable infrastructure development.

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Enhancing energy transition decision-making through resilience integration: A review

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ABSTRACT: Energy resilience is generally defined as an energy system's ability to adjust to an unforeseen shock. In every integration of resilience for energy transition decisions, the particulars of the case and context are crucial. Although identifying all the potentially relevant case- and context-specific factors and their interrelations for any case is probably impossible, the identification of some elements is crucial to making an informed decision regarding which aspect of energy planning should be the focus of any decision. The article used a systematic review to identify parameters for enhancing energy transition decision through resilience integration. The parameters cover energy value chains, the nature of disruption, resilience strategies or approaches, the anchor of energy resilience, the type of resilience, and the scope of application of resilience strategies. The outcome of this study would help decision-makers acquire a reasonable amount of knowledge about different facets of resilience applications within the energy sector.

Keywords: energy resilience, sustainable energy assessment, parameter, sustainability

1 INTRODUCTION

Energy resilience is generally acknowledged as the capacity of an energy system to adjust to an unforeseen shock (Molyneaux *et al.* 2016). Energy resilience, like other infrastructure resilience, is now at the centre of the overall planning, design, and management of energy infrastructure (Upadhyaya *et al.* 2021). Infrastructure and services in developed countries' urban areas have established reliable definitions of resilience and its dependence on various factors as an important pathway for achieving sustainability in these energy systems (Mazur *et al.* 2019). It is attracting more and more attention among government regulators and academic researchers, and it is also supposed to counter or absorb undesirable disruptions (Zaijing and Dapeng 2018). Even now, system resiliency assessment is becoming more important, and incorporating it into energy sustainability assessment for both pre- and post-implementation appraisal cannot be overemphasized. Various attempts have been made to understand energy resilience assessment from different perspectives. At the community level, energy resilience layers include engineering, operational, and community resilience (Shandizl *et al.* 2020) while the approaches for explaining energy resilience are engineering, ecological, and socio-ecological resilience (Jesse *et al.* 2019; Sharifi & Yamagata 2015). Curves, indicators, models, and methods are the means for assessing resilience (Lund *et al.* 2021). There are two main types of resilience indicators, depending on the energy system being appraised:

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capacity (attribute-based) indicators and performance in the presence of disruption (performance-based) indicators (Martišauskas *et al.* 2022). Panteli *et al.* (2017) contrast the resilience triangle and resilience trapezoid to describe the quantitative measurement of resilience. Resilience complements traditional static system performance measures (such as sustainability) to consider behaviours under changing conditions and complex interactions among physical, informational, and human domains (Roege *et al.* 2014). Energy system resilience is strongly linked to the types of threats and energy systems in question. This limits a generalization of the concept and may necessitate a better specification or categorization of the cases considered (Lund *et al.* 2021). In every integration of resilience for sustainable energy decisions, the particulars of the case and context are crucial. Although identifying all the potentially relevant case- and context-specific factors and their interrelations for any case is probably impossible (Gaudreau and Gibson 2010), identification of some elements is crucial to making an informed decision regarding which aspect of energy planning should be the focus of any assessment for the effectiveness of policies integrating sustainability and resilience objectives. Although some studies have improved decision-makers' understanding of specific considerations for resilience assessment in the energy sector (Gatto and Drago 2020; Lund *et al.* 2021; Sharifi & Yamagata 2015), there is still limited knowledge about the necessary parameters to consider for resilience inclusive energy transition decision-making. Addressing wide range of threats to the energy system requires having appropriate knowledge of the main elements influencing the mitigation and adaptation practices in cities (Sharifi and Yamagata 2014). Consequently, this article used existing literature to identify parameters for integrating resilience as part of energy transitions decisions given new knowledge required for energy policy on the achievement of both sustainability and resilience objectives simultaneously for energy transition. The following sections discuss the study's method, the parameters for incorporating resilience into energy transition decision-making, discussion and conclusion.

2 METHOD

This paper is part of the preliminary stages of the development of integrated sustainability and resilience decision support for the energy transition in sub-Saharan Africa. Systematic literature review (SLR) methodology is considered appropriate for this study because it is regarded as a comprehensive framework to explore the literature (Dashtpeyma and Ghodsi 2021) and the context of this study, which is integration resilience into sustainable energy decision-making. The steps implemented in the study are: (i) formulating review questions; (ii) locating the studies; (iii) selecting and evaluating the studies; (iv) analyzing and synthesizing; and (v) reporting and using results (Lassio *et al.* 2021; López-Castro & Solano-Charris 2021). Therefore, the main question addressed is, what are the main parameters for enhancing energy transition decision through resilience integration? To locate the literature for the study, the Scopus database was preferred because it has a wider and stronger collection of interdisciplinary journals, about 20 per cent more coverage than its counterpart Web of Science (Falagas *et al.* 2008; Pranckutė 2021), and a daily update of the database compared to WoS, which is weekly (Burnham 2006). In the first instance, a preliminary desk study was done between January and May 2023 to promote comprehension and familiarity with pertinent concepts related to resilience and sustainability. This exercise helped to generate specific keywords used for searching the database and increased the accuracy and completeness of the review (Negri *et al.* 2021). Additionally, López-Castro & Solano-Charris (2021) and Negri *et al.* (2021) provided guidance in framing the search strings due to their conceptual similarities with this study, although applications are in different knowledge areas (Qazi *et al.* 2019). The 'title, abstract, and author's keywords' option was used for the search with the following string: (TITLE - ABS-KEY (sustainab* OR green AND resilien* AND energy AND assess* OR framework OR evalut* OR criteria OR indicator*)).

The selected papers were: empirical research papers; in the field of energy; and in the English language, taking into account that publications in articles written in English would have undergone a thorough peer review process (Olawumi 2020), and around 80 per cent of all indexed journals are in English, as cited in (Bahji *et al.* 2023). Papers that did not meet the inclusion criteria with an exception (Gatto and Drago 2020a) (which has the attributes of a review paper) were excluded from the study. The initial search results were filtered out by exclusion criteria, which eliminate irrelevant papers. These include papers that do not explicitly focus on energy systems or value chains, such as generation, distribution, supply, and transmission, as well as grey literature, such as theses, project deliverables, and working papers. Most grey literature usually are converted into papers, which would result in duplication if they were incorporated into the literature review. A few articles that were identified during the preliminary review on Google Scholar continue to appear in the search results following various filtering processes. This seems to verify the stability of the search results. Consequently, 314 articles were generated, of which 299 were available for download. Further review of the article abstract led to the identification of 87 articles, which were downloaded into Microsoft Excel Spreadsheet Mendeley Reference Manager. Finally, 34 papers were selected for critical review after two consecutive full-text perusals of the publications. The list of articles are presented in appendix 1.

3 PARAMETERS FOR ENHANCING ENERGY TRANSITION DECISION THROUGH RESILIENCE INTEGRATION

Addressing the question raised in the method section on the main parameters for enhancing energy transition decision through resilience integration, this article identified five parameters, which include energy value chains, nature of disruption, resilience approach, anchor of energy resilience, and scope of application of strategies. The summary of the parameters is provided in Table 1. Energy value chain represents the stages or activities necessary to make energy available for end-use. Value chain is considered the first consideration in energy decision-making because each stage of energy production will have its own unique influences, threats, or shocks, producing different performances. According to Table 1, the stages are energy generation, transportation/transmission, distribution, and consumption. Decisions can be made on the entire system (Ahmadi *et al.* 2021; Babalola *et al.* 2022), the energy sector (Gatto and Drago 2020), market forces such as demand for energy (Pal and Shankar 2023) and multiple chains (Hasheminasab *et al.* 2020; Moslehi and Reddy 2018). The next parameter is the nature of threats or disruptions that could affect energy value chains. Threats increase the energy system's vulnerability and can lead to low performance, thereby significantly affecting service delivery. Decision-making process must take into account the types of threats peculiar to the value chain being addressed. According to the synthesis of the articles reviewed, there are ten groups of threats: climate, demand, economic, human/management, natural events, operational, technical, policy, resource, and epidemic (pandemic). The complete list of threats are in the appendix 1. When decisions are made on the entire system (Ahmadi *et al.* 2021; Gatto & Drago 2020b; Yazdanie 2023; Yazdi *et al.* 2023), disruptions are an aggregate of threats to each value chain. Decision makers could choose to concentrate on specific threats, as observed in (Dong *et al.* 2021) and (Ahmadi *et al.* 2021), which concentrate on the risk of emissions and natural disasters, respectively. Table 1 further presents strategies (approaches) for reducing the impact of threats (increasing resilience), which are adaptation, anticipation and prevention, recovery, and transformation. Anchors of resilience help to achieve the listed strategies, reflecting attributes or initiatives that make energy system more resilience. The attributes common in the reviewed articles includes degree of diversity, quality, stability, decentralization, flexibility, integration, market concentration, supply, reliability, robustness, and technology maturity. These characteristics can also be used to measure the performance energy system in terms of resilience.

Finally, scoping the integration of resilience for energy transition decisions helps establish the context in which resilience strategies could be applied and assessed. The scope can include community-level or wider urban coverage, such as continent, sub-continental, or global. Scoping could help you figure out how big the threat(s) are or what kinds of shocks are unique to a situation, which could help you decide how complicated (or not) a strategy should be. The appendix has a summary of the reviewed articles based on the parameters.

Table 1. Resilience parameters.

Parameters	Aspects
Value chain	Generation, transmission/transportation, storage, distribution, consumption and energy system in general
Nature threat/ disruption	Relating to: climate, demand, economic, human/ management, natural, operational, pandemic, policy, resources, technical/technological
Approach to resilience	Adaptive, recovery, absorptive, anticipative, transformative, preventive
Anchor of resilience	Degree of diversity, quality, stability, decentralization, flexibility, integration, market concentration supply, reliability, robustness and technology maturity
Scope of application	National, local/community, power plant/energy generation/project/specific system, global, city/urban/municipal, organizational, continent, sub-continent

4 DISCUSSION

The uniqueness of integrating resilience into energy transition decision-making, which involves specifying specific case and context, necessitates identifying parameters for structuring decisions. The study identified value chains, nature of disruption, resilience approach, anchor of energy resilience, and scope of application of strategies as aspects necessary to achieve this objective. As expected, the combination of different parameters generated different meanings of resilience in existing studies. For example, it is energy security (Ala *et al.* 2023), the adaptive capacity to improve performance through learning and adaptation, informed by continuous change (Gatto and Drago 2020), and the diversity quality of the system, viewed from the perspectives of energy security and social responsibility (Kharsrazi *et al.* 2015; Mujjuni *et al.* 2021). It has also been explained using the concept of inertia, interpreted as how long it will take a system to diversify (fossil-based systems may do so gradually) (Herbert *et al.* 2016), the number of people that are affected by disaster (the fewer, the better) (Teah *et al.* 2019), and reasonable risk value (Wang *et al.* 2021) among others. According to Lund *et al.* (2021), a resilient energy system can build upon the abundant experiences and knowledge about threats from different energy security and reliability studies. Schweikert & Deinert (2019) noted that identifying specific vulnerabilities allows for better communication, planning, and situation-specific interventions. Thus, by focusing on specific aspect decision-makers would be on the path to proffering adaptive solution for stable, secured and reliable energy system.

5 CONCLUSION

This study addressed the main parameters for enhancing energy transition decisions through resilience integration. This is important because in every incorporation of resilience for energy decisions, the particulars of the case and context are inevitable. This study leveraged the strengths of a systematic literature review as a comprehensive framework to explore the literature in a specific field using the Scopus database to identify articles for review. The parameters include energy value chains, the nature of disruption, resilience strategies or approaches, the anchor of energy resilience, the type of resilience, and the scope of application of resilience strategies. Since energy resilience is fundamental to international development and meeting sustainable development goals, the knowledge of different facets of energy resilience as revealed in this study would support planning for resilient energy infrastructure. It can provide guidance on generating metrics for resilience inclusive sustainability evaluation of energy investment decisions, as well as post-investment performance tracking of energy projects, resulting to tenable initiatives for improvement. The outcome of this study contributes to the authors' ongoing study on the development of decision support for integrating sustainability and resilience for the energy transition in sub-Saharan Africa. A future study should involve an actual application in case studies to assess how well the parameters can support inclusion of resilience for energy transitions decisions since it has only been presented conceptually.

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Appendix 1. Summary of the reviewed articles based on the parameters.

Articles	Type of disruption	Value-chain	Strategy	Anchor	Scope
(Afgan and Veziroglu 2012)	Change of the system parameters (chemical, physical and technical)	G-T-S-D-C	Adaptive, recovery	Stability of system	-
(Ahmadi *et al.* 2021)	Natural disasters (drought)	ES	Recovery	Stability	UTOPIA energy system
(Ala *et al.* 2023)	Shortage of sources Unequal distribution of energy	G	Adaptive	Diversity Decentralizationeconomy of scale	National
(Amin *et al.* 2023)	Climate change	D	Adaptive	Dispatch Strategy Size optimization	Local – refugee camp hospital

(*continued*)

Appendix 1. Continued

Articles	Type of disruption	Value-chain	Strategy	Anchor	Scope
(Babalola *et al.* 2022)	Unreliable grid connections or power supplies through conventional supply	G-S	Adaptive	Diversity Decentralization	Local – village
(Beriro *et al.* 2022)	Climate change Limited sources	G	Adaptive	Diversity	Energy generation
(Cano-andrade 2017)		G	Recovery, agility	Decentralization	Regional
(Dashtpeyma and Ghodsi 2021)	Political, financial	G	Adaptive	Performance quality	Organizational
(Dashtpeyma and Ghodsi 2022)	Political, financial, social	G	Adaptive	Compatibility with environment quality and quantity	Power plant
(Dong *et al.* 2021)	Risk of emission	ES	Adaptive	Quality, diversity	Global
(Eras-almeida *et al.* 2020)	Climate	G-D	Adaptive	Diversity, stability, reliability	Galapagos Islands
(Gatto and Drago 2020)			Adaptive	Flexibility, adaptability	
(Grafakos and Flamos 2015)	Climate change	G	Adaptive	Market concentration supply, stability of generation tech. maturity, innovative ability	Local
(Grafakos *et al.* 2015)	Climate change	G	Adaptive	Diversity	Local
(Grafakos *et al.* 2017)	Climate change	G	Adaptive	Market concentration supply, stability of generation technology, maturity, innovative ability	Local
(Hasheminasab *et al.* 2020).	Nature of projects, technological changes	G-T-S-D-C	Adaptive	Dynamism	Project
(Herbert *et al.* 2016)	Changes in energy and environmental policies, new types of power plants	G	Adaptive	Diversity, flexibility, robustness	Macro/Global
(Jing *et al.* 2021)	Extreme weather	ES	Adaptive	Diversity	City
(Kharrazi *et al.* 2015)	Climate, human mismanagement, technological errors, socio-political turmoil	ES	Functional diversity response diversity	Diversity	Global
(Moslehi and Reddy 2019)	Natural, manmade, random events	G-T-C	Adaptive	Functionality loss	Community
(Mujjuni *et al.* 2021)	COVID-19	De-G-C-D	Preventive, anticipative absorptive, adaptive, recovery, transformative, reliability	Integration, inclusiveness, robustness, redundancy, hardness, rapidity, reflectiveness, efficiency, flexibility, resourcefulness, qualities	National
(Odoi-yorke *et al.* 2022)	Sole source of energy	G	Adaptive	Diversity	Business SMEs
(Odoi-yorke *et al.* 2023)	Resilient to capital subsidies, inflation, discount rate, fit, and wind speed variations.	G	Adaptive	Diversity	Local
(Pal and Shankar 2023)	The irregular demand for distributed energy and large transmission	D	Anticipative Recovery	Integration, diversity	National

(*continued*)

Appendix 1. Continued

Articles	Type of disruption	Value-chain	Strategy	Anchor	Scope
(Pérez-Denicia *et al.* 2021)	Operational representation of an attribute of a system	G	Adaptive	Suitability	10 states
(Phoumin *et al.* 2021)		ES	Adaptive	Quality of infrastructure, Diversity	Continental
(Salehi *et al.* 2022)	Natural disasters, Wars, financial crises	D	Adaptive	Spare capacity	Organizational
(Sharmin and Dhakal 2022)	Climatic and non-climatic	S-T-D	Adaptive	Robustness, stability, flexibility, resourcefulness, coordination capacity, redundancy, diversity, foresight, capacity, independence, interdependence, collaboration, agility, adaptability, self-organization, creativity, efficiency	National
(Spalding-fecher 2003)	External trade impacts	ES	Adaptive	Diversity, quality, reliability of electricity supply	National
(Teah *et al.* 2019)	Natural disaster	ES	-	-	Local community
(Wang *et al.* 2021)	Climate-resilient		Adaptive	Self-sufficiency	Municipal
(Yazdanie 2023)	Climate change	ES	Adaptive Absorptive	Flexibility	power plant
(Yazdi *et al.* 2023)	Natural or artificial events	ES	Preventive, absorption, recovery	Sustainability	National
(Yue *et al.* 2001)	Disaster	G	Adaptive	Diversity, decentralized energy	

G- generation, T- transmission, S- storage, D- distribution, C – consumption, ES – energy system, De- demand

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

The effects of poor delivery of social infrastructure projects in South Africa

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ABSTRACT: Social infrastructure projects (SIPs) are critical to the South African economy. However, most infrastructure projects have not been delivered to the satisfaction of the clients. Therefore, the objective of this paper is to determine the effects of poor delivery of SIPs in Mpumalanga and Limpopo provinces of South Africa. The research data was collected using a questionnaire survey. A total of 103 responses were received. The t-test conducted revealed the respondents agreed that poor delivery of SIPs is associated with some factors, including financial pressure on the contractor, negative impact on return on investment, unnecessary pressure on contractors, poor workmanship, poor service delivery, and stress on the project stakeholders. It is therefore crucial to mitigate against poor delivery of SIPs. The study was limited to Mpumalanga and Limpopo provinces in South Africa; hence the findings cannot be generalized. A nationwide study to compare and validate the current results is recommended.

Keywords: Contractor, Construction, Project Delivery, Social Infrastructure, South Africa

1 INTRODUCTION

The construction projects that are implemented by the government of South Africa are referred to as SIPs. According to the Department of Environmental Affairs and Tourism (2004), SIPs are projects, that cater mainly to the needs of the people in the communities, with the government as the main custodian of the completed project. These are public schools, clinics, hospitals, community health centers (CHC), community halls, community libraries, civic centers, government offices, fire departments, sports facilities, mortuaries, market stalls, heavy-current electrical works, stormwater management, potable water supply, roads, and bridges. SIPs contribute to the local economy by providing job opportunities in the communities where the projects are located (Hussein and Omar 2011). According to Perkins (2011), between 1960 and 2009, the public sector spent an average of US$215 billion of South Africa's Gross Domestic Product (GDP) on infrastructure. The Construction Industry Development Board (CIDB (2021) indicated that in 2020, the construction industry in South Africa accounted for 3% of the country's GDP. This included investments in SIPs like health and education. The construction industry's contribution to GDP was valued at R83 billion. A 10-year, R2.3 trillion investment in infrastructure was launched the same year. More than 1.8 million new jobs were anticipated as a result of the program. There was another announcement of a R1.1 trillion Economic Reconstruction and Recovery Plan, which features infrastructure projects as one of its four pillars of emphasis.

The amount invested in the construction sector affects how much is made and how much value is added to the economy. Despite the importance of the SIPs and the construction industry's contribution to the economy, it emerged that in the 2016/2017 fiscal year, just 26% of SIPs in Mpumalanga province were delivered on time (Mpumalanga Department of Public Works, Road, and Transport 2017). In the fiscal year 2017/2018, 53% of SIPs were not delivered

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on time (Mpumalanga Department of Public Works, Road, and Transport 2018). Although 245 SIPs were planned for fiscal year 2018/2019, only 169 were completed. Furthermore, only 39% of the completed SIPs were finished on schedule (Mpumalanga Department of Public Works, Road, and Transport 2019). In the fiscal year 2019/2020, 48% of SIPs were not delivered on schedule (Mpumalanga Department of Public Works, Road, and Transport 2020).

In Limpopo province, during the 2016–2017 fiscal year, only 51 of the 86 scheduled SIPs were completed within budget and on time. The remaining 35 projects were delayed due to poor project integration management during the planning stages of the projects by the professional team and flaws in the procurement processes by the client and were never implemented in the planned fiscal year (Limpopo Department of Public Works, Road, and Infrastructure 2017). In the 2018–2019 fiscal year, many of the implemented SIPs in Limpopo province experienced slow progress throughout the financial year due to contractors experiencing cash flow challenges due to late or non-payments by the client. Other challenges were due to work stoppages on site by disgruntled communities where the projects were based (Limpopo Department of Public Works, Road, and Infrastructure 2019). In line with the challenges discussed, this study aims to establish the effects of poor delivery of social infrastructure projects in South Africa with a focus on Mpumalanga and Limpopo province. This study provides an analysis of the impacts of poor delivery of SIPs in South Africa, specifically focusing on the under-researched regions of Mpumalanga and Limpopo. It identifies the unique factors contributing to poor delivery in these areas and proposes specific solutions. Through demographic analysis, factor analysis, and t-test results, the study offers new insights and practical recommendations for improving project delivery, making a significant contribution to both academic literature and practical application in the construction sector. The following sections will discuss the literature review, research methodology, results and discussion, conclusions, and recommendations.

2 LITERATURE REVIEW

The government of South Africa has a responsibility to provide and preserve basic public infrastructure. It is a fundamental human right to have access to basic services (Van Heerden 2015). Furthermore, the South African government makes use of infrastructure projects to enhance the country's economy, improve service delivery to communities, and create jobs. Inadequate access to basic infrastructure, which includes water, electricity, roads, and sanitation, contributes significantly to poverty in communities (Van Heerden 2015). Due to the challenges associated with delivering infrastructure projects, SIPs are often poorly delivered (Mashegoana and Khatleli 2019). Emuze and Mhlwa (2015) affirm that many SIPs in South Africa are experiencing quality problems as well as cost and time overruns. These factors contribute to the poor delivery of SIPs. Shibani, Saidani, and Alhajeri (2013) infer that poor planning and implementation of H&S, also contribute to poor delivery of SIPs. Other factors that lead to poor SIP delivery are cancellation of projects by client departments; community disruptions; community rejection of the scope of works; delays in the identification of suitable sites; delays in the procurement system; poor performance by contractors; and late payment by the client (Mpumalanga Department of Public Works, Road and Transport 2019). Further, most SIPs are undertaken by small and medium construction enterprises (SMEs). However, these SMEs in Limpopo province are not financially sustainable, lack technical skills and entrepreneurial abilities, and are therefore unable to deliver SIPs as expected. In addition, the cost of building materials is continuously increasing, which contributes to the challenges faced by SMEs in delivering the SIPs (Limpopo Department of Economic Development, Environment, and Tourism 2022). Furthermore, the effects caused by the poor delivery of SIPs are the repercussions that arise when the causes of poor delivery of SIPs are not effectively mitigated (Mukuka *et al.* 2015). The effects caused by poor delivery SIPs in South Africa are discussed herein:

The effects stemming from the poor delivery of SIPs have been extensively documented in the literature. Inefficient project delivery can have cascading negative effects on various stakeholders. Financially, it often leads to cost overruns, placing a burden on contractors (Hussain *et al.* 2018). This pressure can translate into job losses as construction organizations struggle to maintain profitability (Sastoque *et al.* 2016). For instance, Hussein and Omar (2011) elucidate how inadequate project delivery contributes to job losses within local communities due to heightened financial pressure on contractors, leading to layoffs. Studies in developing countries, including South Africa highlight how poorly managed SIPs result in reduced workforce size due to contractor insolvency (Wai *et al.* 2013).

Poor delivery of SIPs also impacts the project's return on investment negatively. Delays and substandard work can diminish expected benefits, ultimately leading to a poor return on investment (Sierra *et al.* 2017). Perkins (2011) underscores the negative correlation between poor project delivery and return on investment, emphasizing how cost overruns and delays erode investor confidence and reduce long-term economic viability (Love *et al.* 2011). The pressure to meet deadlines and manage budgets in poorly delivered projects can also compromise quality and workmanship. When contractors face undue pressure, they may prioritize speed over quality, resulting in the use of substandard materials or shortcuts in construction practices (Love *et al.* 2011). Smith *et al.* (2016) also highlight the detrimental impact of rushed construction practices resulting from unnecessary pressure on contractors, leading to compromised workmanship. This phenomenon not only undermines project quality but also exacerbates safety incidents and rework (Hussain *et al.* 2018).

The pressure associated with poorly delivered SIPs can create a stressful working environment for team members, leading to decreased morale, burnout, and ultimately, a decline in productivity (Love and Luo 2018). Studies examining the mental health of construction workers found a significant correlation between poorly managed projects and increased stress levels (Sastoque *et al.* 2016). Research suggests a direct correlation between poor delivery and an increase in construction defects (Hussain *et al.* 2018). The consequences of poorly delivered SIPs extend beyond financial considerations. Delays in completing essential infrastructure can disrupt access to vital services like education and healthcare, negatively impacting communities (Loosemore 2011). Poorly delivered sanitation projects, for example, can exacerbate public health issues (Harris *et al.* 2020). Moreover, inadequate infrastructure provision perpetuates social inequities, hindering economic mobility and exacerbating disparities in access to opportunity (Mashegoana and Khatleli 2019). The toll of poor project delivery transcends economic and societal spheres to exact a psychological toll on project team members, leading to stress and attrition (Grum and Grum 2020).

The construction sector contributes massively to the GDP of South Africa, and as a result, it is regarded as one of the biggest job creation platforms in the country. However, poor delivery of construction projects disrupts the value chain of the whole process. For example, additional overheads would add more financial pressure to the contractor. Increases in the prices of materials would negatively affect the profits of the contractor. This may lead to job losses, furthermore, the client or the owner of the property being developed could lose a sizeable amount of return on investments (Oshungade and Kruger 2017), and (Aigbavboa *et al.* 2014). Kikwasi (2012) maintains that bankruptcy, construction project disputes, delays by the client to pay back the loans, stress on contractors, and negative social impact are some of the effects caused by poor delivery of construction projects.

The construction industry's distinct characteristics require the engagement of several stakeholders throughout the project's life cycle. They further explained that when there are several stakeholders in a project, there is a high likelihood of conflict. Poor delivery of SIPs may tarnish the project stakeholders' reputation. For instance, disputes can lead to litigation once all other methods of dispute resolution have been exhausted, especially when large penalties are at stake (Mukuka *et al.* 2015). Construction disputes have an impact on all stakeholders involved as a result of poor project delivery. This includes low profits and increased costs. Furthermore, disputes may have an impact on the project's cash flow, insurance premiums, building costs, and the reputation of the stakeholders. (Mashwama *et al.* 2019).

In the preliminary phases of construction projects, contractors plan the construction processes and schedules as precisely as feasible; however, variation orders are inevitable (Kermanshachi and Rouhanizadeh 2019). Construction project delivery is dependent on project duration, and the project duration could be highly influenced by variation orders. Project duration is a determinant of construction project delivery, and variation orders have a significant impact on project duration.

Applying schedule pressure momentarily enhances productivity on site when the completion date is set, but over time it leads the project to extend beyond the baseline duration. Furthermore, applying schedule pressure creates labour discontentment and, as a result, a decline in labour productivity, which could lead to an increase in variation orders (Kermanshachi and Rouhanizadeh 2019).

According to Oshungade and Kruger (2017), poor delivery of SIPs causes unnecessary pressure on contractors due to the cost of rework and additional time spent on the project. Rework during construction may negatively impact a project's budget and schedule. In such circumstances, the project manager's emphasis is on completing work more quickly with the available resources, which results in straining the resources. Project managers may prioritize carrying out the project scope or carrying out rework. As a result, quality assurance efficacy may decline because of not paying attention to it, which might lead to certain mistakes going unnoticed and being accepted as work that was successfully performed (Li and Taylor 2011).

3 METHODOLOGY

The study assessed the effects caused by poor delivery of SIPs in Mpumalanga and Limpopo provinces. This study adopted the quantitative method, and a survey research strategy was utilized. This method was found suitable to gather data from a broad sample, allowing for quantitative analysis of key variables related to SIP delivery, as related studies have preferred the same research method (Gulino *et al.* 2020). The survey was implemented by administering a questionnaire to a population sample (Saunders *et al.* 2009). The questionnaire included the demographics of the respondents and the effects caused by poor delivery of SIPs in Limpopo and Mpumalanga provinces. A 5-point Likert scale was used to measure the effects caused by poor delivery of SIPs. The researcher used a simple random sampling technique to determine the respondents. To achieve the sample size, a margin of error is 5% was used. Therefore, a 95% confidence interval (CI) was used (Gilliland and Melfi 2010). The sample size was 124 which was sampled from a population of 600 target respondents. The response was 103 respondents, suggesting a response rate of 83%. The data was obtained from consultants, contractors, client representatives, and other construction workers who worked on SIPs. The data was analyzed using descriptive and inferential statistics. The Statistical Package for Social Sciences (SPSS) version 28 was used to analyze the data. In analyzing the data gathered, information on the respondent's background was analyzed using percentages, while the effects caused by poor delivery of SIPs were determined using mean score and t-test. The reliability and validity of the study were achieved through internal consistency reliability and construct validity methods. Cronbach alpha and Exploratory factor analysis (EFA) were used to determine the internal consistency and construct validity respectively of the statements measuring the effects caused by poor delivery of SIPs.

4 RESULTS AND DISCUSSION

4.1 *Demographic characteristics*

Data analysis indicated that 37 respondents (36%) were consultants, followed by 26 respondents (25%) who were contractors, 24 respondents (23%) were client representatives, and 16 respondents (16%) were other construction workers, which included construction supervisors and site foremen. There was a total of 103 out of 124 participants. Regarding professional registration, 57 respondents (56%) working in SIPs are not registered. Professional quantity surveyors account for 17 respondents (17%), professional construction managers account for 14 respondents (14%), professional architects account for 8%, and professional engineers account for 6%. The results revealed that the respondents who hold university degrees and postgraduate degrees have the highest frequencies of 39 and 32 respondents (i.e., 38 and 31%), respectively. This indicates that most of the respondents have university degrees, followed by national diploma with 27 respondents (i.e., 26%), matric certificates with 4 respondents (i.e., 4%), and other, i.e., Trade certificates with 1 respondent (i.e., 1%). In terms of formal job experience in SIPs, the results indicate that the majority of those who participated in this research are experienced. There are 36 individuals (38%) who have more than 11 years of formal work experience. Followed by 59 respondents (i.e., 62%) with an average of 3 years of formal work experience in the SIPs.

4.2 *EFA for effects caused by poor delivery of SIPS*

The EFA for effects caused by poor delivery of SIPs in Table 1 indicates the eigenvalue for factor 1(1.822) is greater than 1, suggesting a one-factor model was confirmed in line with the literature. This factor explains a total of 36.44% of the variance and was further retained for further investigation.

Table 1. Percentage variance - effects caused by of poor delivery of SIPs.

Components	Eigenvalues	% of Explained variables	Cumulative %
EC1	1.822	36.442	36.442
EC2	0.943	18.866	55.308
EC3	0.885	17.704	73.013
EC4	0.742	14.834	87.847
EC5	0.608	12.153	100.000

Table 2 shows the factor loadings for the effects caused by poor delivery of SIPs variables: EC1- job losses due to increased financial pressure on the contractor, EC2 - poor delivery of SIPs negatively influences return on investment, EC3 - late delivery of projects causes unnecessary pressure to contractors that lead to poor workmanship, EC4 - poor delivery of SIPs adversely affects the society due to poor service delivery, and EC5 - causes stress on the project team members, were all above the factor loading required of 0.30. Therefore, the statements measured the effects caused by poor delivery of SIPs. However, the internal consistency was weak (α=0.55). Despite the weak internal consistency, the scale was maintained as the construct was not used as a predictor variable.

Table 2. Factor loadings for effects caused by poor delivery of SIPs.

Variables	Factor α=0.55
EC1	0.329
EC2	0.335
EC3	0.316
EC4	0.312
EC5	0.362

4.3 *T-test for effects caused by poor delivery of SIPS*

To assess the difference in participants' responses between those who agreed and those who disagreed, t-test results are presented in Table 3. Assuming that the numbers 1–5 on the Likert scale are continuous interval data, applying t-test statistics will mean that the data is continuous. Then 3 can be treated as a reference point for the middle number, referencing uncertainty in the Likert scale. The following criteria are applied in analyzing and interpreting the meaning of the t-test outcomes: If the majority of participants agreed, where the mean > the reference point of 3 and the p-value is less than 0.05, then there is strong evidence to conclude that the majority of participants agreed with the statement under test. If the majority of participants disagreed if the mean < 3 and the p-value was less than 0.05, then there is strong evidence to conclude that the majority of participants disagreed with the statement under test. If participants are unsure if a mean = reference point of 3 and that p-value is greater or equal to 0.05, then the conclusion is that we can conclude that participants are not sure about the statement under test. The results imply that there is strong evidence to conclude that most of the participants agreed that poor delivery of projects could lead to job losses due to increased financial pressure on the contractor (EC1), as the mean value was above the median of 3. This argument is corroborated by research by Oshungade and Kruger (2017) and Aigbavboa, Thwala, and Mukuka (2014), which indicate that additional overheads would put the contractor under greater financial strain, and increase the prices of materials that would negatively influence the profits of the contractor. There is also evidence to indicate that poor delivery of projects adversely affects return on investment (EC2). This statement is supported by Oshungade and Kruger (2017) and Aigbavboa, Thwala, and Mukuka (2014), which suggests that the client or owner of the land being developed might lose a substantial amount of return on investments due to poor delivery of a construction project. Late delivery of projects causes unnecessary pressure on constructors and leads to poor workmanship (EC3). Oshungade and Kruger (2017) similarly maintain that late delivery of SIPs causes unnecessary pressure on contractors and leads to poor workmanship. Poor delivery of SIPs negatively influences the communities due to poor service delivery (EC4). The results also reveal that poor delivery of SIPs causes stress on the project team members (EC5). There are several instances of inadequate service delivery throughout the provinces of Mpumalanga and Limpopo because of incomplete or abandoned SIPs, including incomplete roads, incomplete water supply schemes, clinics, and other public facilities that provide essential services to the communities. The results are consistent with Kikwasi's (2012) study, which argues that stress on contractors and negative social impact are some of the effects caused by poor delivery of construction projects. This is proven by the mean values of the statements being significantly greater than 3.00 and the p-values being less than 0.05. Furthermore, the overall mean value of 4.30 and p-value of less than 0.05 validate the results of the individual statements defining the effect of delivery of SIPs in Limpopo and Mpumalanga Provinces. The results suggest that the respondents significantly agreed with all the effects of poor delivery of SIPs.

Table 3. One-sample t-test for effects caused by poor delivery.

	Test Value = 3							
One Sample Statistics	N	Mean	Std Deviation	T	df	Sig. (2-tailed)		Majority Agree
EC1	103	3.97	1.071	9.203	102	0	<0.05	Yes
EC2	102	4.04	0.889	11.805	101	0	<0.05	Yes
EC3	103	4.10	1.080	10.307	102	0	<0.05	Yes
EC4	103	4.55	0.638	24.729	102	0	<0.05	Yes
EC5	103	4.19	0.742	16.340	102	0	<0.05	Yes
Average	**102.8**	**4.30**	**0.884**	**18.136**	**102**	**0**	**<0.05**	**Yes**

Given the issues identified with the delivery of SIPs, some strategies can be proposed to mitigate these problems. Enhanced project management training is crucial, as specialized programs focusing on risk management, time management, and financial planning can improve project delivery outcomes. Improved stakeholder engagement is also essential; regular and effective communication between all stakeholders, including government bodies, contractors, and community members, can lead to better project alignment and accountability. The implementation of advanced technologies such as project management software can also help to streamline processes, improve accuracy in project timelines, and reduce delays. Stricter regulatory oversight, through more rigorous frameworks and regular audits, can help ensure that projects are completed on time and within budget, reducing the risk of poor workmanship and financial strain. Finally, introducing performance-based incentives for contractors can motivate them to adhere to project schedules and maintain high-quality standards, thus improving overall project outcomes.

This study provides an analysis of the impacts of poor delivery of SIPs in South Africa, highlighting the need for systemic changes in the management and execution of such projects. The study makes a specific contribution to the delivery of social infrastructure, which has received less research effort in the Mpumalanga and Limpopo provinces of South Africa. The research determined specific factors causing poor delivery of SIPs in these regions and proposed relevant solutions to address these issues. The study used demographic analysis, factor analysis, and t-test results to examine different perspectives that contribute to a deeper understanding of the challenges and potential remedies for poor delivery of SIPs in the construction sector. The findings have significant implications for policymakers, project managers, and stakeholders in the construction industry, offering a pathway to more effective and efficient project delivery in future SIPs. This study not only confirms and expands upon existing literature but also provides practical recommendations that can be implemented to improve service delivery in construction projects, thereby making a valuable contribution to both theory and practice.

5 CONCLUSIONS

The findings revealed there was statistically significant agreement on the effects caused by poor delivery of SIPs in Mpumalanga and Limpopo provinces of South Africa. There are several instances of inadequate service delivery throughout the provinces of Mpumalanga and Limpopo as a result of incomplete or abandoned SIPs, including incomplete roads, incomplete water supply schemes, clinics, and other public facilities that provide essential services to the community. Financial pressure due to additional overheads, non-payments by the client, and increase in the prices of materials would put contractors under greater financial strain, and impair their profits. This research provides empirical evidence of the effects of poor delivery of SIPs in Mpumalanga and Limpopo province in South Africa. In addition, the research has revealed that there is strong evidence to deduce that most of the participants agreed that poor delivery of SIPs could lead to job losses due to increased financial pressure on the contractor. It was established also that poor delivery of projects adversely affects the return on investment. Further, late delivery of projects causes unnecessary pressure on constructors and leads to poor workmanship. It was further deduced that poor delivery of SIPs negatively influences the communities and causes stress on the project team members.

6 RECOMMENDATIONS

Based on the study's findings, it is recommended to enhance project management training, improve stakeholder engagement, adopt advanced technologies, strengthen regulatory oversight, and introduce performance-based incentives for contractors. These measures aim to address challenges in SIPs delivery in South Africa, offering practical solutions to improve project efficiency and outcomes. The findings suggest that stakeholders in these provinces should mitigate these effects to enhance the successful delivery of SIPs. However, these findings cannot be generalized, as the study was limited to two provinces in South Africa. Therefore, the authors advocate for a comparative study across all provincial governments in South Africa and other developing countries to determine whether these challenges are unique to specific regions or common across South Africa and other developing countries.

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Theme 3: Infrastructure investment & finance – trends & forecasts

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Infrastructure as an asset class: A critical literature review and case study analysis

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ABSTRACT: The objectives of this paper are to reflect and assess infrastructure as an asset class and to analyse the regulatory changes that are underway to allow institutional investors to play a larger role in infrastructure investment. The methodology to address the objectives was a systematic review of infrastructure-related literature and case study analysis of institutional investment in infrastructure from selected African countries. The findings from the study showed that investment features of infrastructure contribute to making infrastructure a unique investment prospect for public and private investors. The research has also analysed regulatory changes to Regulation 28 under the South African Pension Funds Act 24 of 1956 that are intended to foster more investment into infrastructure through private equity. The research presents practical implications for institutional investors, with regard to the different infrastructure related financial products and investment channels which they can pursue in infrastructure investing on the African continent.

Keywords: Infrastructure, Asset Class, Institutional Investors

1 INTRODUCTION

Infrastructure is a key driver of economic growth and prosperity. It is important for the development, functioning and prosperity of a country and provides the underlying foundation for countries to thrive. Adequate infrastructure for proper water and sanitation, reliable and sufficient power supply, efficient transport networks and cutting-edge information and communication technology contribute to the sustainable and economic growth of countries (Arimah 2016). It also promotes the competitiveness of local businesses, improves the productivity of workers, and enhances investment and mobility within the country. Basic economic growth theory identifies different channels through which infrastructure can positively impact economic growth. These channels include infrastructure as a factor of production as well as a complement to other factors of production. Infrastructure is a stimulus to aggregate demand as well as a stimulus to factor accumulation and infrastructure as a tool of industrial policy. While the G20 has highlighted the importance of infrastructure for growth and development, the world however still faces a massive gap in financing for investment in new and existing infrastructure. This is generating a major bottleneck to economic growth and development or provisions of secure and reliable public services. As such the G20 has stressed the need to scale up infrastructure investment through exploring innovative mechanisms to crowd-in private capital (OECD 2018). One such innovation is the classification of infrastructure as an asset class, to attract investment from institutional investors. Institutional investors are constantly searching for stable opportunities that can match their long-term liabilities. Positioning infrastructure as such an opportunity will go a long way in attracting more investment. As such, the objective of this paper is to reflect on this area and assess infrastructure as an asset class. The focus of the study will primarily be on the African

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continent and the regulatory changes that are underway to allow institutional investors to play a larger role in infrastructure investment.

2 RESEARCH METHODOLOGY

The methodology followed in addressing the objectives of the study embodies the following two approaches. Firstly, a systematic review of existing literature regarding infrastructure as an asset class. The systematic review was conducted in the following five steps: Framing questions for a review; Identifying relevant work through desktop search; Assessing the quality of studies; Summarizing the evidence; and Interpreting the findings. The questions framed for the review were: how infrastructure is a financial product; what infrastructure risks and rewards are; what infrastructure investment vehicles are; what the methods of investing in infrastructure are; what the roles and challenges of institutional investors are when investing in infrastructure; and what regulatory frameworks for institutional investors are in place to encourage such investing. Through a desktop search for each framed question, relevant literature was identified and assessed based on quality. The literature was then summarised, and the findings were interpreted in section 3 of this paper. Secondly, case studies were conducted which focused on pension funds, sovereign wealth funds and other institutional investors who have invested in infrastructure and analysed key factors that could have prompted these investments. The case studies include Nigeria's Viathan Funding Plc and Kenya's Nairobi-Nakuru-Mau Summit Road. The Viathan Funding Plc and the Nairobi-Nakuru-Mau Summit Road have been selected because Nigeria and Kenya have the second and third largest pension fund assets under management in Africa respectively (Bright Africa 2018). The choice of these specific case studies in each of the two countries for this research was also based on the availability of data.

3 RESEARCH RESULTS AND DISCUSSION

The research results and discussion section are divided into two subsections. The first is the systematic literature review section which is divided into subsections which document both local and international literature with regards to infrastructure and its economic and investment properties. The second is the case study analysis section, which is divided into three subsections, each from an African country where institutional investors have invested in infrastructure as an asset class.

3.1 *Literature review*

3.1.1 *The emergence of infrastructure as a financial product*

The infrastructure investment gap cannot be fully financed by traditional sources of public finances alone. The impact of the COVID-19 pandemic has exacerbated the situation by reducing the scope for public investment in infrastructure within government budgets which has resulted in seeking more private sector participation. Economic infrastructure is more likely to generate commercial returns on investment and attract private finance, whereas the obligation for social infrastructure is primarily to meet social needs. Returns for social infrastructure often do not cover the costs and as such investment is typically financed by the public sector. However, both economic and social infrastructure are important foundations for long-term sustainable development. The investment characteristics of infrastructure are generally associated with predictable and stable cash flows which are inflation hedged over a long-term period. Infrastructure as an asset also exhibits low sensitivity to volatility as well as low default rates. Infrastructure also has economic characteristics such as a high barrier to entry, economies of scale and inelastic demand for services. Infrastructure also has low operating costs, high target operating margins and a long duration, which all contribute to making infrastructure a unique investment prospect for public and private investors. Infrastructure investments provide liability matching for investors like pension funds which invest more in long-term results and defined outcomes as opposed to speculative short-term results which are prone to high volatility (Croce 2011).

3.1.2 *Infrastructure risk and rewards*

Due to the heterogeneous nature of infrastructure, investors are provided with a range of risk and return profiles within the asset class (Sharma 2013). Investment in infrastructure development such as greenfield developments is expected to have the highest returns but also the highest risk. These can include new toll roads, power plants, airports, desalination, and rail infrastructure. Investment in brownfield assets is associated with lower risk and returns as compared to greenfield assets (Sharma 2013). These can include seasoned toll roads, social infrastructure, electricity generation, gas processing and ports. Since institutional investors prefer investments with low risk, brownfield assets are more popular among them (Sharma 2013). Generally, returns to infrastructure assets, especially in the network sectors, have low return volatility due to their monopolistic nature, relatively inelastic consumer demand for services and high barriers to entry. There are other risks associated with investing in infrastructure such as government regulations, political factors, construction process, liquidity, and currency risk (Sharma 2013). The OECD (2015) classified the three main infrastructure investment risks as political and regulatory, macroeconomic, business and technical. Political and regulatory risk arises from government actions such as changes in policies and regulations which can adversely impact infrastructure investments. In general, political risk is difficult to price into infrastructure finance as it is highly subjective and difficult to quantify (OECD 2015). Macroeconomic and business risks arise from the volatility of industries and the economic environment. It is manifested in variables such as inflation, real interest rates and exchange rate fluctuations. A principal business risk of an asset can be the asset's exposure to the business cycle (shifts in demand) and financial risks such as debt maturity. Technical risks are associated with construction, skills of the operators and managers, and project complexities (OECD 2015). To mitigate risk, governments should create a more conducive institutional environment by providing compensations that increase returns to investors and make the investment more attractive (OECD 2015). Governments can also minimize the magnitudes of political and regulatory risk by honouring the terms of the agreements and developing reliable guidance on construction costs and tariffs. To mitigate business risk in infrastructure investment, the transparency and availability of information to forecast revenue and cost and to effectively manage operations is paramount for investors to make informed investment decisions(OECD 2015). Technical risks can be mitigated through the know-how of specialized operators and could be co-managed with the private sector to generate an incentive for effective project delivery (OECD 2015).

3.1.3 *Infrastructure investment vehicles*

Investments in infrastructure can be channelled through multiple investment vehicles. The main investment vehicles are equities and bonds. With these approaches, there are several direct, indirect, listed, and unlisted channels through which an investment can be made (Figures 1 and 2). The vehicle selected for investment will therefore depend on several factors linked to a particular investor's mandate, risk appetite and investment horizon (Rajiv 2013).

3.1.3.1 *Equity*

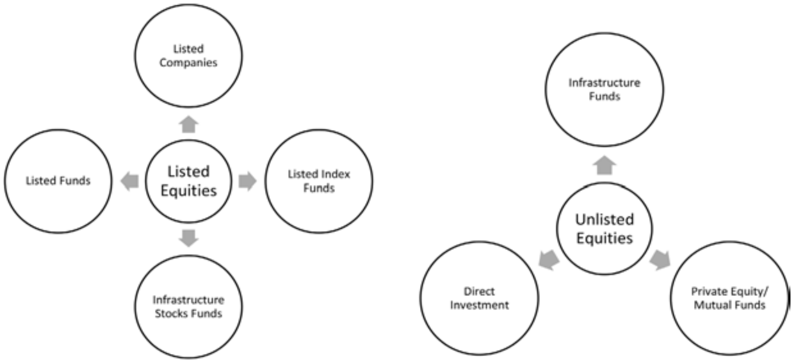

Figure 1. Investment channels through equities. Sources: Adapted from Rajiv (2013) and Inderst and Stewart (2014).

Investment through listed equities has traditionally been popular for energy and transport companies. Infrastructure projects have historically been run and operated mainly by publicly-listed companies including construction and engineering groups. The structure of listed infrastructure funds is such that an external manager invests on behalf of investors in various infrastructure assets. The assets invested in by the fund may or may not be listed even though the fund is publicly listed. The listed infrastructure index funds have also given retail and institutional investors an opportunity to invest in well-established stock market indices which contain listed infrastructure companies. In South Africa, the Satrix global infrastructure exchange traded fund which is trading on the Johannesburg Stock Exchange has offered investors an investment vehicle that gives them exposure to a diversified portfolio of the largest and most liquid infrastructure companies in developed and emerging markets (JSE 2021). However, in recent years, new investment vehicles such as unlisted equities and mutual funds have been created for those not able or willing to make their investments (Croce 2011). Unlisted equities refer to equity investment in a company that is not listed on a stock exchange and the value of the company is therefore not directly affected by stock market sentiment. Direct investments in infrastructure typically exhibit a lower correlation with traditional asset classes and can provide a useful hedge against volatility in other asset classes. Infrastructure funds have gained popularity among investors as they enable them to invest in a range of diversified projects to spread their risk (Pautz, *et al.* 2018). Investors in these funds invest as limited partners as the fund is managed by the general partner which is often an investment bank or management firm. The general partner then invests contributions to the fund in various infrastructure assets on behalf of the limited partners.

3.1.3.2 *Debt* Infrastructure debt investing provides investors with two approaches, through the capital markets or private debt. In the post-financial crisis era infrastructure debt funds have increased in prominence as a contraction in credit markets has made sourcing long-term funding for both new developments and asset refinancing difficult (Rajiv 2013). Such funds offer investment in assets that are relatively safe but offer a yield higher than government bonds and are inflation-adjusted. Investing in the capital markets offers either direct or indirect investments in instruments such as corporate bonds in infrastructure companies, government backed securities, municipal bonds and infrastructure bonds earmarked for specific infrastructure projects. There is also an investment opportunity in investing in Public Private Partnerships bonds and also in investing in Private debt which involves institutional investors extending loans to infrastructure companies and projects.

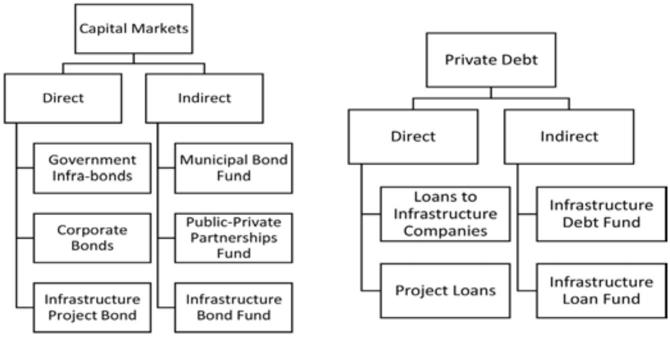

Figure 2. Investment channels through debt. Sources: Adapted from Rajiv (2013) and Inderst and Stewart (2014).

3.1.4 *Methods of investment*

The methods of investment into infrastructure can take many forms as can be seen in Figure 3. The choice between direct and indirect investing depends largely on the institutional investors' internal resource capabilities and their reliance on investment consultants or fund managers. For indirect investing in unlisted equity, institutional investors such as pension funds invest in infrastructure assets through infrastructure fund managers and/or investment consultants. When investing through a fund manager, all the responsibilities of the investment fall onto the fund manager. The fund manager has a role in sourcing appropriate assets to invest in on behalf of institutional investors, while the investment consultant usually provides advice to the institutional investor about infrastructure investing and which fund managers to choose. Regarding direct investing, institutional investors have in-house investment experts who source infrastructure assets to invest in and maintain. In this case, consultants and fund managers are usually not required as the institutional investor has the requisite capability and capacity. Direct investment can also be made alongside co-investment partners in a consortium consisting of other institutional investors and infrastructure fund managers (Rajiv 2013). In a consortium, the largest institutional investor leads the transaction, and the equity arrangement of the investors varies from asset to asset.

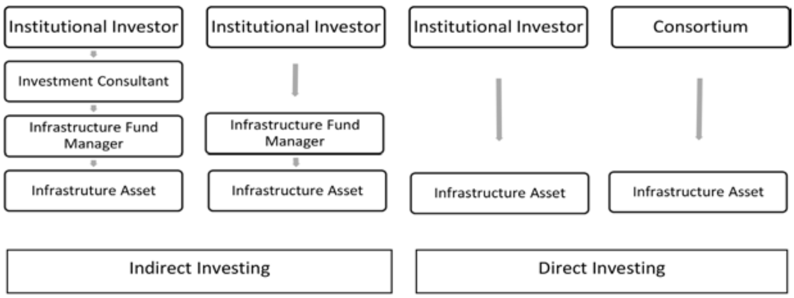

Figure 3. Structural forms of the Infrastructure investment process. Sources: Adopted from Andonov, *et al.* (2018).

3.1.5 *The role of institutional investors in infrastructure financing*

An institutional investor is an organization that pools money and invests it on behalf of clients or members (Chen 2021). Institutional investors encompass large organisations such as finance companies, pension funds, insurance companies, mutual funds, and unit trusts. However, this study focuses mainly on the role of pension funds and sovereign wealth funds.

The pension funds industry has become the largest source of savings in the global economy and plays an important role in supporting investments through their ability to pool stable, long-term savings and direct these into appropriate investments to generate a return. Factors that have contributed to the upward trend of pension fund assets include the evolution of people having a pension plan, their contributions, the benefits that these plans pay to retirees and the financial performance of pension assets. There are two kinds of pension plans, funded and unfunded pension plans. Unfunded pension plans are social security systems whereby the pensions of the retirees are paid from the contributions of the current working population (Kagan 2021). As no money is set aside, there needs to be enough people working to make contributions to pay for those who have retired. This might be problematic because the current working population can retire early and as such there may be a current working population that is smaller than the retired population. On the other hand, funded pension plans require the employee and the employer to set aside money each month so that the contributions can be invested, and a return earned to fund employee retirement (Kagan 2021).

The structure of pension funds affects the attractiveness of infrastructure investment. Most pension funds are either defined benefit (DB) or defined contribution (DC). In a defined benefit (DB) plan the employee's pension benefit entitlement is determined by a formula which considers years of service for the employer and, in most cases, salaries and wages. Under a defined contribution (DC) plan, each employee has an account into which the employer and, if it is a contributory plan, the employee makes regular contributions. The benefit levels depend on the total contributions and investment earnings of the accumulation in the account (Bodie, *et al.* 1988). The extended life of infrastructure and the long-term nature of the concession rights for associated investments make them a suitable match for the long-term liabilities of a pension fund. Due to the monopolistic nature of infrastructure, which has a high barrier to market entry and inelastic demand for the use of the asset, cash flows of infrastructure investments are normally stable and predictable. Cash flows such as user tolls, airline charges or rail tickets are often inflation linked which provides pension funds protection against volatility and inflation.

Pension funds can also invest in infrastructure to diversify risk, as the returns have a low correlation with returns of other asset classes (Rajiv 2013). There are differences between DC and DB plans that affect their suitability for investing in infrastructure. The DC plan focuses on the value of the assets currently endowing a retirement account, while the DB plan focuses on the flow of benefits which the individual will receive upon retirement (Bodie, *et al.* 1988). During an employee's working life, the DB retirement benefits are implicitly indexed to inflation, which leads to greater benefits accruing towards the end of the employee's working life. On the other hand, DC plans are independent of inflation as employers can achieve any backloading pattern by choosing an appropriate pattern of contribution rates over the course of the employee's working life (Bodie, *et al.* 1988). Therefore, DB plan administrators looking to match liabilities will be attracted to investing in greenfield infrastructure, as it is an asset with a long-term horizon, inflation linked and has volatility-protected cash flows. In contrast, the DC plan administrators prefer to invest in more liquid investments to be able to trade out their assets quickly and reduce the risk of losses. This raises a concern for DC plans as infrastructure assets might not be as liquid. As such, DB plan providers have invested more in infrastructure assets than DC plan providers (Rajiv 2013). Sovereign wealth funds (SWFs) are special-purpose investment funds or arrangements owned by a government whose purpose is either to ensure that a country's resources are preserved for future generations or to stabilize government fiscal and/or foreign exchange revenues and macroeconomic aggregates (OECD 2015). Several African countries, especially those with oil and gas endowments, have established SWFs. These SWFs were established for the following reasons: accrual of savings, wealth diversification, economic stabilization, safeguards against economic shocks and domestic investments in line with their investment mandates (Pautz, *et al.* 2018). SWFs establish sub-funds that make direct investments in infrastructure to comply with their investment mandates. SWFs do not require high levels of liquidity and are more likely to invest in greenfield infrastructure, much like DB plans. They also generally take on more risk as they are not directly linked to individual employee pensions.

3.1.6 *Key challenges for pension funds and SWFs investing in infrastructure*

From an investment point of view, there are certain challenges and barriers that affect the willingness of institutional investors to invest in infrastructure. Institutional investors are subject to strict regulatory funding and solvency regimes and accounting rules (Inderst and Stewart 2014). One of the key challenges for pension funds and SWFs is a limited number of financial instruments and funds regarding infrastructure. Many countries in Africa suffer from the lack of publicly listed infrastructure securities, which is a major constraint inhibiting investments. This can be attributed to the lack of developed capital markets with less liquidity which do not satisfy the preferences of institutional investors in the continent (Pautz, *et al.* 2018). However, private equity infrastructure funds have become a more feasible option for investors to invest in as they have a proven track record. Another challenge is the lack of expertise within the infrastructure sector. Since investing in infrastructure is a relatively new concept, institutional investors prefer to invest in traditional assets (government bonds, equities, and treasury bills) which they are more familiar with. A better understanding of infrastructure as an asset class is required by asset managers to overcome this hurdle. There is also the lack of political commitment over the long term as well as the lack of bankable infrastructure projects that are still prevalent. Project bankability is determined at an early stage and comes down to project preparation. Other government issues such as regulatory thresholds for infrastructure investments and high bidding costs do place barriers on institutional investors (Inderst and Stewart 2014).

3.1.7 *Role of regulatory frameworks in attracting investment in infrastructure*

The Code for Responsible Investing in South Africa (CRISA) guides how institutional investors should execute investment analysis and investment activities and promote sound governance (National Treasury 2021). Regulation 28 under the South African Pension Funds Act 24 of 1956 came into effect in July 2011 and included a new requirement for retirement funds to consider environmental and social issues in assessing factors that materially affect the sustainable long-term performance of retirement fund assets (National Treasury 2021). Regulation 28 has been reviewed and amended in 2022 to encourage increased investment in infrastructure given the current low economic growth rate in South Africa. Investing in infrastructure has been permitted under Regulation 28 though the regulation did not define infrastructure as a specific category. The amendment has introduced a definition of infrastructure to be able to measure the exposure of retirement funds to infrastructure assets (National Treasury 2021). The definition of infrastructure is any asset class that entails physical assets constructed for the provision of social and economic utilities or benefits for the public (National Treasury 2021). The amendment also states that overall investment in infrastructure across all asset classes may not exceed 45 percent of the aggregate fair value of the total assets of the fund which also includes a limit of 10 percent in respect of infrastructure in the rest of Africa, while a 25 percent limit was also introduced per single issuer or project (National Treasury 2021). To further increase infrastructure investment, the asset category relating to "hedge funds, private equity funds and other assets not referred to in the schedule" has been split into "hedge funds", "private equity" and "any other assets not listed in this schedule" as stand-alone asset classes. After this split, the overall limit for private equity funds has been proposed to increase from 10 percent to 15 percent (National Treasury 2021). The increase in private equity limits is due to several studies which concluded that private equity investments in infrastructure have a positive impact on the economy and help in diversifying project risk between project sponsors (Amardien and Gillmer 2021).

3.2 *Case studies*

3.2.1 *Viathan funding SPV (Infrastructure Bond)*

Viathan Engineering Limited, which is owned by the private equity firm Synergy Private Equity, issued Nigeria's debut 10-year corporate infrastructure bond in local currency to raise 10 billion naira at a yield of 16 percent to fund power assets in January 2018 (Reuters 2018). The Viathan group specializes in captive and embedded power generation, providing modular, last-mile, scalable power-as-a-service to the end user quicker, cheaper, and more efficiently to governmental, industrial, commercial, and other service markets (Viathan 2021). The Viathan bonds were raised through Viathan Funding Plc, which is a special purpose vehicle established to raise debt capital. The repayment obligations on the bonds issued to the investors under the programme were the joint and several obligations of the co-obligors ("borrowers") contracting as primary obligors to the bonds alongside the SPV under the programme trust geed. The net proceeds under the programme are passed through and/or advanced to the co-obligors under the terms of the trust deed and/or a Master Intercompany Loan Agreement as specified in the applicable final terms. The co-obligors, directly on a joint and several bases, make full payment to the interests and principal due on the bonds to bondholders pursuant to the trust deed via the payment account held by the bond trustee. The Viathan bonds were backed by an irrevocable and unconditional guarantee of InfraCredit. This is 'AAA' long term national scale rated infrastructure credit enhancement facility established as a commercial entity by the Nigeria Sovereign Investment Authority and GuarantCo to provide guarantees to enhance the credit quality of local currency debt instruments issued to finance eligible infrastructure assets in Nigeria (Viathan 2018). InfraCredit acted as a catalyst to attract institutional investors such as pensions and insurance firms and as such the Viathan bonds were subscribed by twelve pension funds and two insurance firms (Reuters 2018). A total of NGN 10,5 billion was raised resulting in a 105 percent subscription and the nominal yield of the bonds was 16 percent (Viathan 2018). The proceeds from the bonds were intended to be used to expand the power generation capacity by 7,5 MW and build a compressed natural gas plant. This is seen as a good opportunity for a long-term investment with a good return (16 percent nominal yield) (Pautz, *et al.* 2018). This case study shows that positioning infrastructure as an asset class by the issuance of infrastructure bonds can increase investment in infrastructure. This is evidenced by the over subscription of Nigeria's debut 10-year corporate infrastructure bond. The investment characteristics include stable and guaranteed returns which is also a good diversification strategy for investors.

3.2.2 *Nairobi-Nakuru-Mau Summit Road*

The Nairobi-Nakuru-Mau Summit Road project is an expansion of and improvement to an existing highway in Kenya. The highway connects the Port of Mombasa via Nairobi to Malaba, near the Uganda border (Kenya Treasury 2016). Because of the worsening conditions of the road due to the increased traffic on the road, the government of Kenya, through the contracting authority, Kenya National Highway Authority (KeNHA), aims to improve the road through a public private partnership scheme. KeNHA has designed the project as a 30-year design-build-finance-operate-maintain and transfer arrangement. The concessionaire will use a special purpose vehicle (SPV) to improve and widen the road. KeNHA intends to make regular performance related service payments to the SPV which will be stated in the project agreement and a National Toll Fund will be responsible for collecting tolling revenues (KeNHA 2018). Nine Kenyan pension plans formed a coalition to invest in local infrastructure and the first project which the consortium has considered to invest in is the Nairobi-Nakuru-Mau Summit Road. The consortium intends to invest a combined equivalent of USD 70 million in local currency in the project once the contract is awarded (Jacobius 2018). The project is a very attractive investment opportunity for institutional investors as it is an International Development Association (IDA) guaranteed product. The

IDA guarantee aims to mitigate the risk of payment default either by the National Toll Fund or by the Government of Kenya to the SPV. Another key aspect that has made this investment attractive to institutional investors is that there is a high demand for the road due to its location and the project is led by partners with extensive experience in infrastructure projects (Pautz, *et al.* 2018). The project is to be led by French Infrastructure firm Vinci and was expected to begin in September 2021, however, construction on the project has been delayed due to delays in finalizing funding and concluding contracts (Ngugi 2022). This case study shows that positioning infrastructure as an asset class by positioning the Nairobi-Nakuru-Mau Summit Road infrastructure project as an investment product with stable returns, increases investment within the infrastructure project.

4 PRACTICAL IMPLICATIONS

This research presents practical implications for institutional investors such as pension funds and sovereign wealth funds, regarding the different infrastructure-related financial products and investment channels which they can pursue in infrastructure on the African continent. There is a large infrastructure financing gap in Africa, and institutional investors are required to close this gap by investing in infrastructure, which presents risks and returns that are ideal for them and fosters economic growth.

5 CONCLUSION

This research has shown that positioning infrastructure as an asset class is key to unlocking institutional investment into infrastructure and fostering economic growth. The paper analysed the features of infrastructure as an asset and aligned them with the investment needs of institutional investors such as pension funds and SWFs. These features include attractive returns and long-term and predictable cash flows which are inflation hedged over a long-term period. Infrastructure as an asset exhibits low sensitivity to volatility in the economy as well as low default rates. Infrastructure has economic characteristics such as a high barrier to entry, economies of scale and inelastic demand for services which all contribute to making infrastructure a unique investment prospect for public and private investors.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Affordable housing developments: The perspective of financial institutions in Harare, Zimbabwe

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ABSTRACT: The paper aims to ascertain perspectives of Financial Institutions (FIs) regarding Affordable Housing (AH) developments in Harare. Through an exploratory qualitative design, the paper set out to explore risk/return criteria among FIs that invest in AH. The study found that densified AH and stands (subdivided land) are a high priority investment among FIs. FIs avoid land without title deeds as it is not possible to link it to investors who demand to see the value of land, they are to invest in. FIs that engage in construction of AH use conventional building standards and materials to avoid risk of low-quality AH. The conclusion is that a focus on rental AH rather than homeownership alone is a solution to AH inadequacy. Rental AH supply can be used by institutional investors to channel funds into the much-needed AH developments via the listed secondary markets, a new Zimbabwean investment vehicle.

Keywords: Affordable housing, Financial Institutions, Risk-return criteria, Title Deeds

1 INTRODUCTION

A country of slightly above 15 million people with an urbanization rate of 1.72% is no exception to Affordable Housing (AH) as demand (1,3 million) for sustainable and affordable housing far outweighs supply (CAHF 2022). Defined in extent literature this 'supply' should be 'sustainable affordable' housing which does not exhaust resources of future generations and that households are able to pay between 30% and 40% of their combined incomes in mortgage repayments or rental payments monthly (Anacker 2019; Festus *et al.* 2021). Rural-urban migration plays a big part in there being excess housing demand. Informal settlements remain congested as they are the first point of landing for people who move and migrate to bigger cities such as Harare in search of employment (Kährik *et al.* 2016). The challenges of overcrowded spaces include burst sewerage systems as people are usually unemployed and homeless (indigent). Sustainable affordable housing creates a means to fulfil the Sustainable Development Goal (SDG) 11 of making cities and human settlements inclusive, safe, resilient, and sustainable (Taiwo *et al.* 2020).

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According to the Centre for Affordable Housing Finance (CAHF) (2022), the Zimbabwean Government aimed to deliver 300,000 housing units annually in Harare, but this target has not been met due to challenges associated with COVID-19 (Housing, Communities and Local Government Committee 2019). Affordable housing completions in Harare are categorized into statutory, voluntary, and private sectors (CAHF 2022). Statutory completions are managed by local authorities, voluntary completions by housing associations, and private completions by private sector companies. Consequently, the responsibility of supply falls on statutory and voluntary sectors where it is unprofitable for the private sector. Globally, governments encourage greater private sector involvement in financing and developing affordable housing (AH) to ensure future generations can live, work, and play without burden (Ezennia 2022). Mixed-use developments are advocated for their economic and climate benefits in terms of sustainability. In Zimbabwe, McCarthy and Stone dominate the AH market, controlling approximately 70% and offering various categories of affordable housing for outright purchase, part buy/part rent, or rental. Rent-to-buy models are also highly recommended (Susilawati 2009). This private investment typically yields an average initial return of 8.50% (CAHF, ibid). Land access for housing in Zimbabwe is challenging. Most local authorities have depleted their land resources and must rely on the state, a process often delayed (Mutsindikwa *et al.* 2015, p. 99). Developers are acquiring land on the periphery of local government jurisdictions to avoid cumbersome by-laws, poor service delivery, and building permit approval processes (Poshai *et al.* 2024; Taruvinga 2019). Green construction financing is scarce as lending institutions shy away from long-term projects due to economic uncertainties, exacerbating the affordable housing deficit (Simbanegavi 2019b; Yeganeh *et al.* 2021).

Consequently, construction finance interest rates can be as high as 15%-20%. The Central African Building Society (CABS) offers interest rates of 12% for developers in high-density areas and 15% in low-density areas. Lenders have partnered with the government and employers to offer subsidized loans for affordable housing. One innovative product is the 'Cash-Plus Housing Savings Product' by CBZ Bank, which requires clients to save for a year to qualify for a loan equivalent to their savings. However, foreclosures and defaults have hindered its success, posing a credit risk to banks and developers. Therefore, developers who utilize private equity are more likely to succeed in Zimbabwe. Most private developers in Zimbabwe have reduced development costs to supply affordable housing (Chigwenya 2019). However, Daniel *et al.*, (2023) presents a different perspective, concluding that housing developers prioritize profit over addressing the housing gap. Their study found that developers engage in opportunistic behaviors, such as creating artificial land scarcity by holding onto acquired land until its value increases. This behavior suggests that the housing supply issue is not solely due to land shortages (Huang *et al.* 2015; Owusu-Ansah *et al.* 2019; Yan *et al.* 2014).

Leading developers have a significant role in the type, location, and target market of affordable housing, impacting end users. Despite these challenges, the affordable residential property market in Zimbabwe remains limited, with only 3% of the total private affordable housing units. However, rental housing supply is expected to grow from 5,000 units in 2020 to 13,000 units in 2024, driven by the demand for 'care housing' for the aging population (CAHF 2022). Stands, as popularly known in Zimbabwe, is the dominant option available in the AH market. Thus, a blend of products, including inclusive housing for the old and the physically challenged for rental seems viable and this makes a case for institutional investors (Montezuma 2006). However, evidence from the US indicates that convincing investors of the opportunity may not be straightforward. Worzala *et al.*, (2009) examined fund managers' perceptions towards investing in affordable housing in the US and found that affordable housing was low on their list of priorities due to unfavorable risk and return ratios. However, Worzala *et al.*, (ibid) argued that this was due to a lack of understanding of this subsector. It is evident that there is inadequate AH in Harare to cope with the current levels of demand because AH investment is not well understood. Although the statutory and voluntary sectors contribute to the pool, future supply is likely to be led by the private sector, where it is deemed profitable (CAHF 2022). This paper aims to understand the experiences of Financial Institutions (FI) in Zimbabwe regarding their investments within the four stages of the residential property process. The main objective of this paper is to show the kind of risks that FIs have faced and the strategies they have used to promote AH development.

2 LITERATURE REVIEW

Investment theory posits that a sound investment asset preserves the value of invested capital over time while providing returns commensurate with the risks undertaken (Graaskamp 1992). Consequently, the relationship between risk and return hinges on the assumption that rational investors are risk-averse and thus expect higher returns as the level of risk increases. The principal rationale for investing in residential property lies in its risk-return profile compared to other investment assets and its diversification potential (Aalbers 2017; Adair *et al.* 2003a; Adair *et al.* 2007). Successful residential developments require environments that offer rewards commensurate with the risks incurred. Development potential, income stability, capital value stability, liability matching, lower obsolescence, and positive correlation with inflation are also significant attractions (Barlindhaug and Nordal 2018). Financial institutions (FIs) such as CABS, CBZ, FBC, Fidelity, National Building Society, ZB Bank, Tetrad Investment Bank Limited, Standard Chartered Bank, Stanbic Bank, People's Own Savings Bank, Nedbank Zimbabwe Limited, Steward Bank, NMB, First Capital Bank, FBC Building Society, and Met Bank resumed financing housing development, particularly after the introduction of the multi-currency system in 2009, following a halt due to economic crises in Zimbabwe (Mutsindikwa *et al.* 2015).

There exists a research gap in the direct property investment literature regarding whether affordable housing (AH) yields superior returns compared to other property assets such as retail and office assets (Amed *et al.* 2020; Wakely 2020; Waldron & Wijburg 2020). AH investors can find opportunities in the four stages of the development process if the specified risks are minimized. The property development process manages all real estate development projects and oversees the maintenance of all real assets from planning, inception, monitoring, evaluation, completion, and post-completion monitoring to ensure delivery within the required scope. AH projects are managed from concept design to handover and include refurbishments, space rationalization, lifecycle management, and renewal. Despite the extensive literature on AH, there is limited research exploring AH investment in Zimbabwe from the perspective of financial institutions (FIs). Guiding questions for this study include: Is affordable housing a high priority on your list of investments? What are your expert views on land acquisition for AH in Zimbabwe? What are your expert views on affordable housing development projects regarding actual construction? How have you been disposing of your housing units to the market; selling the AH units (sale/hold)? What are your reasons for the options you mention in the previous question? For those who opt to keep the stock for rent, what has been the performance of the rental stock? What are your expert views on Commercial Affordable Housing for rent? Can a Residential REIT work in Zimbabwe as an important potential vehicle for attracting large-scale institutional investment into private rental housing? What are your overall expert views on AH?

3 METHODOLOGICAL APPROACH

Through an exploratory qualitative design, the study aimed to explore perspectives on affordable housing (AH) investments among financial institutions (FIs) in Harare. Non-random sampling was employed, with purposive selection based on participants' experience criteria of more than three years across relevant urban market sectors. This method was chosen to ensure insightful contributions regarding the future of AH developments. Purposive sampling identified research informants among FIs, and interviews provided insights into different stages of the AH development process. Following Tan *et al.*, (2017), semi-structured interviews targeted decision-makers in the AH industry from institutions with a national-scale mandate. In-depth, one-on-one interviews were conducted with ten research informants holding diverse roles within the FIs. Guided and unguided site visits allowed for non-participant observations collected in March and April 2023. Discussions with FI officers and real estate agents further informed the study. Document reviews and non-participant observations were triangulated, with interview data carrying more weight. This multi-method strategy included preliminary data from site visits, interviews, and random face-to-face interviews, resulting in handwritten notes that were incorporated into the study. The study adopted a semi-structured, conversational setup allowing for two-way communication and flexibility. A thematic approach was used to analyze interview data. Saturation was reached after eight interviews with experts having at least ten years of industry experience. The final nodes captured responses to each specific question, facilitating color coding as part of the thematic analysis, linking data to propositions iteratively. Pseudonyms ensured privacy and confidentiality for interviewees, who signed consent forms. Interviews lasted between 20 minutes to one hour.

4 RESULTS & DISCUSSION

The results were triangulated, with interview data carrying more weight than data from documents and observations. Current projects include the Fontaine Ridge housing project by FBC Building Society in Kuwadzana, featuring various models (1, 2, 3, 4, and 7 rooms) on average stand sizes of $240m^2$. This development includes municipal water, sewers, tarred roads, and electricity. Other AH projects, such as Knockmalloch, Norton, Magakooshla in Shurugwi, and Amalinda Park housing cluster, offer incremental housing where buyers can choose completed or partially completed houses based on mortgage affordability. Another significant player in the AH sector is ZB Bank, with projects in many Zimbabwean cities and towns. The bank has strategic partnerships with local authorities for residential and infrastructure development. To date, ZB Bank has constructed over 3,000 units, including housing units and serviced stands. Notable projects include 10 townhouse units in Hatfield completed in 2015 and 890 serviced stands in Springvale, Ruwa. The FI aims to significantly reduce the national housing shortage through site and service as well as housing units. The interview data highlighted the role of financial institutions (FIs) in various stages of affordable housing (AH) development, including land acquisition, construction, disposition, rental decisions, and the involvement of real estate investment trusts (REITs) in completing the AH supply chain. The results are discussed under seven themes outlined in the study's hypotheses. Using thematic analysis, some hypotheses were accepted while others were rejected. To address contradictions in the results, the Delphi method was employed for a second stage of data collection, involving two experts who evaluated the research findings. Their feedback helped synthesize and rationalize differing views from the initial interview data, achieving a theoretical replication for accuracy, as a result this study presents only findings which confirm its hypotheses.

4.1 *AH real estate is a high priority investments*

Overall, the results indicate that residential real estate is a high-priority investment for financial institutions (FIs) in Zimbabwe, particularly in serviced land investments. The FIs agree that affordable housing (AH) offers positive returns that justify the associated risks. FI1 commented, "We have faced challenges with inflation and currency issues in the past, but now we understand the AH business rules, specifically pegging all asset sales in USD to protect our returns." The resilience of AH real estate is driven by the significant housing demand exceeding supply in Zimbabwe (CAHF 2022).

4.2 *Land acquisition for AH*

The study found that densified affordable housing (AH) and subdivided land (stands) are high-priority investments for financial institutions (FIs). All interviewed FIs indicated that they purchase land from the open market, noting that land in Zimbabwe is reasonably priced. They avoid land without title deeds, as it cannot be linked to investors who need to see its value. FIs typically do not buy land from municipalities. FI10 stated, "Land in the periphery is preferable as it avoids stringent municipal zoning regulations." Generally, inner-city land is more expensive (Graaskamp 1992), whereas peripheral land, which FIs primarily use for AH, is cheaper, the expert emphasized.

4.3 *The actual construction of AH projects*

Financial institutions (FIs) involved in constructing affordable housing (AH) use conventional building standards and materials to mitigate the risk of low-quality outcomes. Most FIs employ in-house planners, engineers, and project managers to avoid the risks associated with subcontracting. They also purchase construction materials using presales funds to counteract the effects of rising inflation in Zimbabwe. FI1 remarked, "We do not trust sustainable green building technologies. We avoid the risks associated with new technologies and stick to conventional methods that we trust. There is little flexibility in building AH on small land sizes." These findings contrast with literature highlighting the benefits of green building and its role in reducing global warming (Simbanegavi *et al.* 2019a).

4.4 *Completed units' disposition to the market*

Most FIs sell affordable housing (AH) units outright on the open market at market prices, as demand still exceeds supply, thereby reducing AH price risks upon completion. Selling AH units reduces business risk and makes AH a viable business model. AH is delivered at competitive market prices, mitigating pricing risk. However, mortgage options are limited and typically have short terms (10 years instead of the usual 25-30 years). Consequently, except for a few FIs, most completed AH units are sold rather than rented. Affordability remains a concern, as one FI noted, "The bank's ambitious mortgage scheme for low-income earners could be hindered by the country's poor economic performance, which shrinks the market as disposable incomes do not keep pace with inflation. The costs of owning a home are too high." Literature supports this finding, indicating that many people are burdened by housing costs to the extent that they resort to renting (Barlindhaug and Nordal 2018; Nurick *et al.* 2018).

4.5 *Reasons behind 'build for outright sale*

Selling affordable housing (AH) units reduces business risk by ensuring continuous market presence and minimizing private equity and structured debt risks, as well as avoiding tenant delinquency. FI6 noted, "Because of high inflation rates, it is best to move in and quickly get out because things change in an instant!" This approach aligns with literature indicating that investors aim to own or hold direct real estate to hedge against rising inflation (Eldomiaty *et al.* 2019; Kola and Kodongo 2017).

4.6 *Building/developing AH for rental stock*

For financial institutions (FIs) that opt to retain affordable housing (AH) units for rent, the performance is favorable, characterized by low vacancies and high-performing leases. Tight maintenance practices ensure rental stocks perform well, and tenant screening helps curtail payment defaults. FI3 remarked, "We have tried building apartments and townhouses for rent, and the performance is good!" This aligns with literature emphasizing the benefits of rental portfolios through REITs, which create an enabling environment for international competitiveness and attract foreign investors (Carstens and Freybote 2018). Focusing on rental AH rather than homeownership is highlighted as a solution to AH inadequacy. Institutional investors can use rental AH supply to channel funds into crucial AH developments via listed secondary markets, utilizing a newly launched REITs investment vehicle in Zimbabwe.

4.7 *Selling the rental AH to REITS*

Most financial institutions (FIs) said that they do not see the value in building rental stock only to sell it to another entity for the same purpose. Therefore, residential REITs in Zimbabwe could succeed if they construct their own rental stock. This preference to hold contrasts with some researchers‘ findings that institutional investors often avoid residential property due to low yields (Manoji 2016; Montezuma 2006; Nurick *et al.* 2018).

5 CRITICAL CONTRIBUTIONS & IMPLICATIONS

The study critically highlights the pivotal role financial institutions (FIs) play in affordable housing (AH) development in Zimbabwe. Triangulated data underscored FIs’ involvement in land acquisition, construction, and market disposition, affirming residential real estate as a high-priority investment despite economic challenges in Zimbabwe. However, reliance on conventional building methods over green technologies reveals a conservative approach that may limit sustainable development benefits. The preference for outright sale over rental aligns with risk aversion strategies amid high inflation, impacting long-term housing affordability and accessibility.

6 CONCLUSION & RECOMMENDATION

The study concludes that financial institutions (FIs) in Harare, Zimbabwe have made substantial investments in affordable housing (AH), focusing on densification and affordability by selling subdivided raw land and providing savings mechanisms for housing affordability. However, despite several AH projects and affordability designs, the depressed mortgage market has limited uptake. The study recommends that FIs prioritize rental AH as a solution to AH inadequacy. Rental AH supply allows institutional investors to channel funds into essential housing through listed secondary markets. Rental stock performance is strong, characterized by low vacancies and high-performance leases. Effective maintenance and management, along with comprehensive tenant screening, ensure rental stocks perform well and minimize payment defaults. The study also suggests that residential REITs could be successful if they construct their own rental stock in Zimbabwe.

7 PRACTICAL IMPLICATIONS

The findings of this study have several practical implications for stakeholders involved in the affordable housing (AH) sector in Zimbabwe. The study underscores the importance for FIs to adopt innovative financing models, such as the ‘Cash-Plus Housing Savings Product,’ to mitigate risks associated with AH investments. Additionally, FIs should consider diversifying their AH portfolios to include more rental properties, which have shown promising performance with low vacancy rates and stable returns. The research highlights the need for policy interventions to streamline land acquisition processes and reduce bureaucratic hurdles. Simplifying these procedures can lower transaction costs and make AH projects more viable for FIs. Moreover, promoting residential REITs can provide a structured and tax-efficient investment vehicle to attract large-scale institutional investments into the AH market.

The study suggests that developers focus strategically on building incremental housing units that align with the affordability levels of low-income households. Developers should also consider partnerships with FIs to leverage financial products that reduce upfront costs for potential homeowners. Local governments should prioritize the provision of bulk infrastructure to support AH developments. Implementing initiatives like South Africa's Strategic Integrated Project (SIP) can lower the cost of serviced land, making AH projects more financially attractive to developers and FIs. The study indicates significant untapped potential in the AH rental market. Investors should explore the feasibility of establishing and managing residential REITs, which could provide steady income streams and contribute to alleviating the housing shortage. By addressing these practical implications, the study provides actionable insights that can guide various stakeholders in enhancing the supply and affordability of housing in Zimbabwe.

8 AUTHOR CONTRIBUTIONS & DECLARATION OF INTEREST

Conceptualization: Prisca Simbanegavi, Nyasha Mutsindikwa, Bekithemba Mpofu, Faranani Gethe. Methodology: Prisca Simbanegavi, Nyasha Mutsindikwa, Cletus Moobela, Malcolm Weaich. Data collection and analysis: Nyasha Mutsindikwa, Prisca Simbanegavi, Pride Ndlovu. Conclusion and recommendation: Prisca Simbanegavi, Nyasha Mutsindikwa, Cletus Moobela. Malcolm Weaich aided in the editing of the paper. The study was partly funded by the Anderson Capelli grant for sabbatical at the University of the Witwatersrand. Informed consent was obtained from all participants. The authors are grateful to the financial institutions in Harare who participated in this study and declare no conflict of interest.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Assessing the efficacy of the urban settlement development grant in facilitating infrastructure development and addressing challenges in South African metropolitan municipalities

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ABSTRACT: Infrastructure development and the provision of affordable housing are key-components to achieving South-African long-term economic goals. The Department of Human Settlements introduced the Urban Settlement Development Grant (USDG) as a supplementary financial-allocation to bolster metropolitan-municipalities' revenue-capitals to promote infrastructure projects. However, it has been a challenge for metropolitan-municipalities to succeed. This study seeks to assess the efficacy of the USDG in contributing to SA's infrastructure development and remedy the challenges encountered in addressing infrastructure-backlogs. This research employs qualitative research methodology, incorporating data collection through open-ended questionnaires, examining historical financial and non-financial performance reports across government spheres. The findings reveals that the USDG has not effectively fulfilled its objectives of leveraging the metropolitan-municipalities' revenue-capitals to finance infrastructure projects, due to the prevalence of suboptimal policies and the irregularities in the USDG expenditures. The study further provided recommendations on strategies to improve the USDG program, ensuring effective contribution to SA's infrastructure development agenda.

Keywords: Human-Settlements, Infrastructure development, Metropolitan Municipality, Service Delivery, Urban Settlement Development Grant

1 INTRODUCTION

Infrastructure development and affordable housing is critical to achieving South African social and long-term economic objectives. Affordable housing and infrastructure delivery is one of the most contributing components to South African's shift from traditionally closed mineral economy to one which is globally integrated. The provision of adequate human settlements with favorable access to social amenities, health, water, and economic opportunities is essential to South African communities and in assisting the country overcome spatial inequality and poverty, also in driving the country's economic growth. Demirguc-kunt (2006) claimed that a well-functioning financial administration is considered vital for economic development.

South Africa has witnessed a perpetual increase in population in the past two decades. As a developing country, the growth in population has major problems associated with it. One major challenge South Africa is facing with regards to population growth, is the need to provide satisfactory living human settlements for the society by creating availability of adequate inexpensive social housing and basic services delivery for people in middle and lower-income class. The need for sufficient and acceptable public roads, bulk civil services such as electricity, sanitation, storm water systems, and road pavements is essential.

The Urban Settlement Development Grant (USDG) was designed by Department of Human Settlement as a significant conditional funding to local government metropolitan municipalities. The grant was established with the aim of funding housing and infrastructure projects as to upgrade human settlements in the local municipalities and lessen the development and expansion of informal settlements. The grant was established in terms of the annual Division of Revenue Bill (DORB) where its policy framework was not properly formulated, and it also lacked a well-defined business plan and program theory. Boadway and Shah (2006) alluded that the issues with a non-well managed programs, formulated business plan and policy frameworks results in decentralization and issues relating to fiscal imbalance.

Despite the greatest efforts and attempts to provide capital budget to metropolitan municipalities through the USDG in order to improve the informal settlements and townships, it has been a considerable challenge to succeed. Some of the reasons associated with the above-mentioned problem are the difficulties in coordinating project implementation between different departments, supply chain management regulations, challenges in defining the supplementary grant output indicators as they are no standard method of monitoring outputs associated with the USDG business plan. The evolving policy framework also makes the grant condition specifications difficult to implement.

The purpose of the research study is to evaluate the role of Urban Settlement Development Grant (USDG), with regards to its contribution to human Settlements in upgrading municipal infrastructures and improving the delivery of services to communities in all South African metropolitan municipalities. The research aims to fill in the gaps and remedy the challenges faced with the USDG in eradicating infrastructure backlogs in poor communities. The following are the potential implications the study would bring: (1) Enhanced municipal capacity: Strengthening municipalities' capacity to deliver basic services and maintain infrastructure by ensuring that allocation of funds is equitable and transparent. (2) Improved living conditions: Upgrading informal settlements and providing basic services like water, sanitation, and electricity, enhancing the quality of life for residents, and uplifting their socio-economic statuses. (3) Enhanced economic opportunities: Supporting local economic development, job creation, and access to social amenities. (4) Formal housing: Creating formal housing opportunities for poor communities and informal settlements, improving tenure security and access to affordable housing.

2 RESEARCH METHODOLOGY

2.1 *Research approach and design*

The research study employed a qualitative research technique, where investigation of noticeable facts was conducted through open-ended questionnaires, historical reporting data, and also examining quantitative financial and non-financial performance reports across various spheres of government with the aim of triangulating the findings from all these data sources to develop a comprehensive understanding of the problem. Qualitative research method was used to gain deeper insight as to why municipalities encounter infrastructure improvement challenges even with intervention of the Urban Settlement Development Grant. Research design entails three main components; data collection, measurement, and analysis. Qualitative research method was best suited for the study because it involves the subjectivities of humans and it seeks to understand what targets the USDG focus on, and reasons behind service delivery backlogs in the human settlement by exploring perceptions and develop solutions to the research problem.

2.2 *Target population*

The target population in this study consisted of seniors from the eight metropolitan municipalities, such as Senior Managers, Chief Financial Officers, Executive Managers and Municipal Mayors. It was crucial that the participants in this research possess at least a minimum of three years having held the municipal office position with background or management of the Urban Settlement Development Grant and infrastructure projects attached to the grant. This is to warrant valid and substantial responses from them.

2.3 *Sampling strategy*

Maheshwari (2017) defined sampling strategy as a plan of action a researcher set out to ensure that the sample used in the investigation represents the population from which it was obtained. In this research study, a judgemental sampling was employed, wherein a non-probabilistic sampling method was used to select units as the research sample based on their background knowledge and professional experience. The sampling technique used in the study was purposive. Units were intentionally selected based on their career background profiles. Metropolitan Municipal officials with minimum of three-years of experience and adequate knowledge in the management of the USDG, were considered as an appropriate target population for this study.

2.4 *Sample size*

The study focused on acquiring data from all eight South African metropolitan municipalities. A total of 24 (3 each municipality) research participation requests were sent electronically to municipal officials who were recognized as relevant participants in the study. The metropolitan municipalities officials were targeted as a sample based on their roles. Executive managers are responsible for all the USDG infrastructure projects issues. Senior managers are responsible for the project management and administration of the USDG. Chief Financial Officers are responsible for projects budgets and financial reporting. Municipal Mayors are responsible for the implementation of policies and programs and establish services the municipality must provide.

2.5 *Data collection methods*

Qualitative research design is conducted by means of using different tools to collect data, such as case studies, literature, surveys, open-ended questionnaires, focus groups and ethnography (Leedy and Ormrod 2010). In this study, the data required to answer research questions was collected from municipal officials using open-ended questionnaires, and by also examining past literature together with historical financial and non-financial performance reports across various spheres of government. Historical documents and literature review contained references to academic resources in order to render knowledge on the following: Urban Settlement Development Grant; Grant schedule strategic goals; allocation of funds criterion; Housing, land, and infrastructure financial trends; Service Delivery and Budget Implementation Plan; Integrated development Plans (IDPs); Municipal Infrastructure Grant and Service delivery within South Africa.

2.6 *Data analysis*

John Tukey (1977) defined data analysis as a process of acquiring raw data and transforming it into practically useful and precise information in order to make decisions or prove a hypothesis. Analysis of the responses given in the open-ended questionnaires from municipal officials was done by identifying common themes in their responses that are significant to this study. The study used qualitative content analysis to interpret data collected from the respondents, literature review and descriptive technique was used to analyze historical financial reports obtained from the government spheres in order to examine the variability of financial datasets. The study followed various qualitative analysis steps: Data collection design; data reduction; data display; data creditability and data dependability.

3 RESEARCH FINDINGS AND DISCUSSION

3.1 *Historical financial and non-financial findings*

3.1.1 *Interpretation and understanding of the USDG*

The variances among metropolitan municipalities were slight, it was observed that there is consistency in the understanding that the Urban Settlement Development Grant is complementary to municipalities' capital budget with the motive of enhancing human settlements and standard of living, particularly by providing bulk infrastructure services to poor communities. The major findings were that municipalities where there is a significant dependence on the Urban Settlement Development Grant were prone to comprehend the Urban Development Grant (USDG) conditions as widely or openly as they could.

Table 1 gives an illustration on metropolitan municipalities' level of dependence on the Urban Settlement Development Grant as a capital funding source and it was depicted from the data, that the level of dependence of metros on the USDG as a principal financing source is indirectly comparable to each metro's capital budget size. The data in the table further indicates that Buffalo City municipality was mostly dependent on the USDG by 82% of the 2013/2014 financial year budget, while Johannesburg metropolitan municipality only depended on the grant for just 20% of its funding capital, with a budget that was ten times (R 7.5 million) more.

The study established that the Ekurhuleni and Buffalo City Metropolitan Municipalities has a much broader definition of the Urban Settlement Development Grant objectives, whereas Johannesburg and Cape Town metropolitan municipalities had focused extensively on bulk

Table 1. Dependence of Metropolitan Municipalities on the USDG as a principal funding source for 2013/2014 fiscal year.

Metropolitan Municipalities	USDG (Millions)	USDG (Percentage)	Other Capital Funding (Millions)
Buffalo City Metropolitan	R 900	82%	R 950
Mangaung Metropolitan	R 900	69%	R 1,100
Nelson Mandela Bay Metropolitan	R 1,000	67%	R 1,400
Ekurhuleni Metropolitan	R 1,500	53%	R 3,000
City of Tshwane Metropolitan	R 1,700	30%	R 4,500
eThekwini Metropolitan	R 1,500	29%	R 5,500
City of Cape Town Metropolitan	R 1,300	22%	R 5,500
City of Johannesburg Metropolitan	R 1,500	20%	R 7,500

Source: Division or Revenue Act (2013)

infrastructure to maintain the delivery of housing units in poor communities. It was substantiated by the minutes of the Human Settlement Portfolio Committee meeting, that Mangaung metropolitan municipality together with the Buffalo City and Nelson Mandela Bay metropolitan municipalities were significantly condemned for using the funds from the Urban Settlement Development Grant on projects and expenditures not intended for.

3.2 *Leveraging municipalities' capital budget through the USDG*

The Urban Settlement Development Grant's design and plan presumes that the USDG will inject more funds to the metropolitan municipalities' budget. The Urban Settlement Development Grant is presumed to enhance the capital finances: (1) by maximizing the financial debts or borrowing of money wherein the Urban Settlement Development Grant will be reserved and utilized as a financial security; (2) by captivating private sectors' financial capital by means of public and private co-partnership projects, in such a way that private developers partners with the state (South African Government) to embark on infrastructure projects beyond the capabilities either party it would have, if managed individually; (3) By funding projects as joint venture with other partners or role-players, though captivation of the metropolitan municipalities' own funds to human settlements orientated projects.

Capital funding trends for every metropolitan municipality between 2008/09 and 2015/16 fiscal year were analyzed, the findings give an indication that the Urban Settlement Development Grant does not necessarily achieve the objective of leveraging the metropolitan municipalities' supplemental capital funds to finance their infrastructure projects and service deliveries to communities. In contrast to that, the Urban Settlement Development Grant has however, displaced or substituted other capital funding sources in Buffalo City, Nelson Mandela Bay and Mangaung and other small-metropolitan municipalities. The most prevalent finding within the metros investigated is that smaller metropolitan municipalities had less counter funding with less reporting on the influence the Urban Settlement Development Grant had over other city fundings than larger metropolitan municipalities. The findings demonstrated that the Urban Settlement Development Grant was solely used to supplement funds for projects belonging to private sector, with limited success to a limited extent.

3.3 *The urban settlement development grant spending challenges*

The metropolitan municipalities had a couple of spending challenges on the Urban Settlement Development Grant. The first challenge they had was to achieve the spending targets stipulated in the USDG conditions. One official from the metropolitan municipality's responses on the spending challenge was that.

> *"The USDG conditions stated that the metropolitan municipalities ought to spend a minimum of 60% of their first allocated funds before they would receive the remaining 40% of the funds by the end of fiscal year. It is challenging to meet or reach the target set in the conditions due to the setbacks in the procurement processes and the construction correlated obstructions."* (Respondent No. 7)

The findings of this can be supported by Matabane (2007), who stated that one of the reasons metropolitan municipalities underspends on the grant was due to the fact that they only start spending in their third-to-fifth month of receiving the funds instead of spending in their first month of the fiscal year. This means the Supply Chain Management (SCM) procedures for that fiscal year only started in the first quarter of the financial year instead of the last quarter of the preceding year.

The second and most common challenge from the findings in this research was that municipalities struggled to spend the Urban Settlement Development Grant allocations while there were civil unrests in local communities, which interrupted the construction progress of the infrastructure projects. One municipal official illustrated the findings the by saying:

> *"In the 2016/2017 fiscal year, there was unrest which occurred in the middle of the year within the Tshwane municipality. The unrest caused the interruption of the infrastructure projects which led to the same projects not been completed by the end of the year, this resulted in an underspending of 23% of the funds that were allocated to them. The municipality lodged an application to roll-over the 23% of the unspent funds to the succeeding fiscal year due to the fact that the projects had already started, and the construction was in progress."* (Respondent No. 5)

The last challenge in relation to the spending of the Urban Settlement Development Grant's funds was stated by one of the Ekurhuleni Metropolitan municipal official claiming that the challenge is due to the inadequate funding that is allocated to metropolitan municipalities. The response was that:

> *"The address of infrastructure backlogs with insufficient funds allocated to municipalities was one of the problematic issues that plunged municipalities into financial strains. First and foremost, municipalities were forced to spend a portion of the funds that were initially allocated or meant to fund sport developments in poor communities. Secondly, municipalities are facing problems due to co-funding issues. Last but not least, the repair, maintenance and the future replacement costs of assets that were funded by the USDG will not be paid for by municipalities' own revenues."* (Respondent No. 2)

The findings above reveal common themes regarding the challenges municipalities are faced with in relation to the utilization of the USDG to address infrastructure backlogs. The common subject matters were that the USDG's underspending causes in majority of municipalities were due to: (1) The problematic and tedious Supply Chain Management (SCM) procedures which delayed the appointment of contractors; (2) The contractors' poor performance; and (3) Civil unrests experienced in local communities due to the dissatisfaction of service delivery, and this are circumstances beyond municipalities' and contractors' control.

The findings can be supported by the Auditor General of South Africa (AGSA) (2016) in the 2014/2015 fiscal year audit results which demonstrated that the spending of the USDG) on projects was one of the main problems that metropolitan municipalities were battling with. AGSA's (2018) findings were that poor project planning and administration principles by municipalities led to influx of spending inadequacies on key projects. This resulted in a substandard quality of work and further delaying projects completion dates. AGSA (2018) also stated that the projects performance targets were usually not met or perhaps were reported inaccurately.

3.4 *Metropolitan municipalities' accountability*

The general findings from the metropolitan municipalities' officials gave an indication that most of these municipalities in this study complied with the accountability cycle with regards to the Urban Settlement Development Grant administration. The Department of Provincial and Local Government's (DPLG) response statement supports the abovementioned findings:

> *"The City of Cape Town, Buffalo City and the eThekwini metropolitan municipalities submits their monthly performance and cost reports to both the provincial and national departments as per the requirements in section 71 of the Division of Revenue (DORA) and the Municipal Finance Management Act (MFMA). The municipalities also submit their financial statements in their annual reports."* (Respondent No. 6)

The Department of Provincial and Local Government (DPLG) (2007) stated that all metropolitan municipalities ought to comply with the Municipal Infrastructure Task Team (MITT) conditions that are primarily managed by the provincial and local governments in order to address the objectives set out in the USDG policy framework. The findings in this study indicates that the City of Cape Town, eThekwini, and

Buffalo City metropolitan municipalities indeed conforms with the accountability cycle with regards to the Urban Settlement Development Grant policy framework, as per the responses given by the Department of Provincial and Local Government which gave evidence to the findings. The provincial department holds the responsibility to ensure that all the metros comply with the USDG policy.

3.5 *Implementation monitoring mechanism of the USDG by the metropolitan municipalities*

One of the themes that emerged from the USDG compliance findings was the level of productiveness of the monitoring systems which were employed to administer the compliance with the USDG conditions. Few municipal officials confirmed that some municipalities complied with the USDG conditions as per the requirements set by Division of Revenue Act (DORA), and that is worthy of commendation. One of the respondents said:

> *"Frequent monthly Urban Settlement Development Grant (USDG) progress meeting held between the Department of Provincial and Local Government (DPLG), metropolitan municipalities, the Department of Cooperate Governance (DCoG) and other department sectors of government which deals with financial administration, communiques, registration of infrastructure projects issues, building capacity and reporting are effective when monitoring the implementation of the USDG. It is also necessary for the Department of Provincial and local Government (DPLG), and the Department of Cooperate Governance to attend the projects site meetings and submit monthly progress reports."* (Respondent No. 2)

The third respondent stated that:

> *"The submission of the Urban Settlement Development Grant monthly cashflow reports is one of the mechanisms put in place to monitor the grant. One other mechanism implemented is by reviewing and verifying the grant spendings quarterly, and the report is signed-off by the Municipal Managers and Chief Financial Officers (CFO)."*(Respondent No. 3)

Additional to the responses above, one respondent stated that:

> *"The Department of Provincial and Local Government (DPLG) also have a monitoring mechanism to keep track of the implementation of the Urban Settlement Development Grant. The DPLG uses a database called AURECOM, which monitors the financial (monthly grant expenditures) outputs, non-financial outputs of projects funded by the USDG, registration of projects, and also ensures that the projects follow the proposed implementation plan. The system updated the database on a daily basis. The Department of Corporate Governance (DCoG) also issues policy frameworks that stipulates what the Provincial Departments can use in order to monitor the implementation of the USDG by the metropolitan municipalities."* (Respondent No. 5)

The responses from the three participants gives indication that through the intergovernmental platforms, the Provincial and National Government work together with all the metropolitan municipalities with the objectives of improving the development of their USDG implementation monitoring mechanisms. A recurrent theme revealed by these findings from the respondents is that the majority of metropolitan municipalities have the USDG monitoring mechanisms in position which they utilize to ensure that the implementation of the grant complies with the relevant policy frameworks and legislations.

3.6 *Metropolitan municipalities' capabilities to monitor the USDG funds*

The metropolitan municipalities ought to establish the Project Management Unit (PMU) in order for them to thoroughly perform their duties and responsibilities in administrating the USDG. The PMU will thus undertake the responsibilities of managing the USDG projects. The respondents in this research claimed that all metropolitan municipalities have a Project Management Unit (PMU) which are ran by the personnels with satisfactory skills and experience to deal with the Urban

Settlement Development Grant (USDG) projects: "All metropolitan municipalities have a Project Management Unit, which all have administrative people, Chief Financial Officers (CFOs), and Chief Engineers."

The Auditor General of South Africa (2018) in their 2016/2017 financial report claimed that the spending on pivotal projects in relation to water and sanitation was flooded with deficiencies, due to poor conformity towards the "sound project and planning and administration" principle. This resulted in substandard quality workmanship and delays in the project completion plan. Nevertheless, the findings in this study gave a clear indication that municipalities have capabilities to manage the Urban Development Settlement Grant.

3.7 *Status of basic service delivery to impoverished communities*

The issues relating to basic service delivery were associated with the satisfaction of the community, the quality of life in communities, and the challenges faced by municipalities in delivering adequate basic services.

3.7.1 *Dissatisfaction of communities with the delivery of basic services*

In association with this subject matter, the respondents in this study were cross-examined to give indication of the degree of satisfaction of the communities with regards to the delivery of services. It was established from the responses that most part of the communities within the metropolitan municipalities were not satisfied with the provision of basic services. The respondents said:

> *"No, communities located in informal settlements are not content or fulfilled with the quality of services provided to them by the municipalities."* (Respondent No.6)

Another respondent in this study said:

> *"No, the is always a backlog of service delivery in townships and informal settlements due to the fact that the municipality drags their feet when it comes to addressing issues relating to provision of services. Municipalities always use 'having limited budget' as excuses to provide basic services. There are always protests taking place in townships and informal settlements which always results in the demolition of public infrastructures in the neighboring urban settlements. The main reasons behind most of the community unrests is due to lack of housing programs for communities, where majority of them lives in backyards."* (Respondent No. 7)

One of the respondents that gave disapproval of the provision of basic services by metropolitan municipalities said:

> *"The communities from ward 4, 8 and 13 located in an established informal settlement are not pleased with the services provided by the City of Cape Town metropolitan municipality. This is due to the high municipal rates, such as electricity and water, where the electricity units do not even last. One of the issues the communities always complain about is the bad storm water management system. The communities always have issues with damp water in their local roads when it rains, where the water ponds to level wherein cars are not able to pass through. Sewage systems are also one of the infrastructures the communities are struggling with, there is always leakages and municipalities take time to respond to this kind of issues."* (Respondent No. 8)

The responses above from the community representative indicates that poor communities in informal settlements are dissatisfied with the delivery of services rendered by municipalities, while in contrast to the communities in established urban settlements like middle-class areas, they are pleased with the services they are provided with by the municipalities. One common issue that was prevalent from communities was that they do not really understand the core functions of the municipalities, because all the complaints raised to the government are shifted to the municipalities. It would be helpful for all metropolitan municipalities and spheres of government to hold a roadshow to upskill communities regarding their functions, as to reduce community unrests due to the dissatisfaction of basic services and non-response to their demands.

3.7.2 *Challenges metropolitan municipalities are faced with in providing basic services*

This part of the study explores the challenges that the metropolitan municipalities encountered in the provision and delivery of basic services to communities in informal and formal settlements. The findings in this study indicated that municipalities do experience basic service delivery challenges. To further give emphasis on this, one respondent from Buffalo City metropolitan municipality shared a view on the challenges relating to the delivery of basic services, that the first difficulty the metropolitan municipalities faced with providing adequate services is the aging of infrastructure which deteriorate over time.

Second challenge was the rehabilitation of this aging infrastructure where municipalities cannot keep up with the repair cost which usually ends up going out of control. Thirdly municipalities never made the provision of rehabilitating landfill sites which create poor living environment for most of the people staying in informal settlements. Lastly, metropolitan municipalities were experiencing continuous difficulty in providing services to poor communities in informal settlements. The increase in population led to an increase in informal settlements which worsened the challenges municipalities are facing in providing basic services.

The findings show evidence that the allocation of funds from the USDG were not sufficient enough to finance either the rehabilitation of old infrastructures, nor the new infrastructure backlogs within the municipalities. The aforementioned finding can be substantiated by Van der Waldt (2015) who argued that there is an imbalance between the Urban Settlement Development Grant and the demands by the municipalities to support poor communities in informal settlements and townships.

Matabane (2017) and Mahachi (2021), also elaborated that the USDG funds are limited, as such the grant is not sufficient enough to address all the infrastructure backlogs experienced by municipalities such as bulk and roads infrastructures. Kopung (2019) claimed that the total expenditure of the USGD allocations does not automatically suggest that the infrastructure or service delivery backlogs have been eradicated. The enforcement of a genuine and a well administered policy framework will help in tracking the USDG's cash flow or expenditures. This will then result in the eradication of infrastructure and basic service delivery backlogs and the minimization of community unrest relating to service delivery.

3.8 *The urban settlement development grant and basic service delivery*

This subdivision of the study explores the USDG's impacts in refining the delivery of adequate basic services in metropolitan municipalities, it further investigates the benefits, assistance, and the role from the communities' perspectives. It looks out at how regularly the USDG projects are maintained by the metropolitan municipalities.

3.8.1 *Maintenance of the USDG projects*

The study revealed that the City of Cape Town, eThekwini, City of Johannesburg, and Nelson Mandela metropolitan municipalities takes effort to maintain their infrastructure services on a regular basis, nevertheless, few respondents had different view on that. Some respondents said:

> *"The municipalities do not usually make effort to rehabilitate infrastructure services in townships and informal settlements, for example there are a lot of buildings municipalities lease to small businesses, and they are in a bad state. Nevertheless, there is taxi ranks that have been upgraded before although further upgrades are still required as the communities are expanding each year and there is a development of new malls which will require transportation facilities."* (Respondent No. 7)

Respondent from the Buffalo City metropolitan municipality argued that the municipality has not been practicing a thing of maintaining old infrastructure projects by saying:

> *"The municipality does not show any signs of being active in promoting a regular infrastructure projects maintenance in townships and informal settlements. The excuses are always relating to the limited budget."* (Respondent No. 8)

> *"The rehabilitation of public roads in towns like Mdantsane and Qonce has been challenging for the municipality. Some of the justification given for not upgrading the roads is that the townships are located in wet areas and a lower topography that floods most the times when there is heavy rainfall, and the roads are being used for heavy traffic which were not designed for. The roads where traffic is low are still in good condition compared*

to those in areas with high traffic. The streetlights are also not in a good state for the safety of both pedestrians, cyclists, and vehicle owners." (Respondent No. 9)

The findings from the respondents illustrates a common theme from responses given by representatives in City of Cape Town, City of Johannesburg, Nelson Mandela and City of Tshwane metropolitan municipalities, that these municipalities do take initiative in maintaining infrastructure services while representatives in Mangaung, Buffalo City, and Ekurhuleni metropolitan municipalities argued that municipalities are not pro-active in maintaining their infrastructure. This finding relates to a response in section 3.7.2, which stated that the rehabilitation of old infrastructure tends to be a challenge as the repair costs increases rapidly, resulting in the disruption of budget allocation for new infrastructure developments. As a result of limited funds allocation for municipalities and revenue they generate for their services versus the number and scale of projects they must implement, these metropolitan municipalities end up allocating less funds for operational costs maintenance of their infrastructure and the delivery of services.

4 CONCLUSION

This study explored the efficacy of the Urban Settlement Development Grant (USDG) in facilitating infrastructure developments and addressing challenges in South African metropolitan municipalities. The study further examined the compliance of the USDG conditions and the difficulties these municipalities are faced with in improving the delivery of services to poor communities. The study presents three significant findings that emerged. The first main finding in this study is that metropolitan municipalities in South Africa have somewhat capabilities to implement the USDG, however, they cannot keep up with an ever-increasing need for new infrastructure projects and the maintenance backlogs of ageing infrastructure with their limited budget. There is a high disparity of the funds municipalities are allocated with, and the demands they must meet by the communities. Secondly, the study revealed that the community representatives only possess general knowledge regarding the USDG, and that it is only meant for projects poor communities. Lastly, while the USDG has positive impact towards the delivery of basic services to poor communities, it is evident that there is still an existence of crucial challenges that need to be resolved, such as the design of adequate policy frameworks.

These abovementioned challenges tend to compromise the quality of lives of people in local communities thus triggering community unrest. Nevertheless, metropolitan municipalities must also perform their duties and maximize the generation of revenues for services they provide to both middle-class and high-income earning communities so that they can co-fund their infrastructure projects that are not aligned to the USDG projects. This would shift them from being entirely dependent on the grant as it is not sustainable.

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The landscape of infrastructure disaster funding in South Africa: An overview from selected literature and documents

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ABSTRACT: This paper presents an overview of the landscape of infrastructure disaster funding in South Africa, with the aim to examine prevalent patterns, challenges, and strategies found in some selected literature and specific documents. Thematic analysis was conducted on selected policy documents, reports, and literature relevant to infrastructure disaster funding in South Africa. The review reveals multifaceted insights into the landscape of infrastructure disaster funding in South Africa. It outlines prevalent trends in funding allocation, and highlights the challenges faced in financing infrastructure for disaster prevention, mitigation, and post-disaster recovery. The findings consolidate existing knowledge and serve as a valuable resource for policymakers, stakeholders, and researchers involved in disaster management and infrastructure development. Moreover, this review provides a foundation for future research endeavours, policy improvements and reforms aimed at disaster risk funding.

Keywords: Infrastructure, Disaster funding, Insurance, Economic growth, Disaster management

1 INTRODUCTION

A disaster is characterized as a catastrophic event causing injury, loss of life, and significant societal and economic disruption beyond the capacity of the affected community to manage (Kamara *et al.* 2018). It is essential to underscore that the mere presence of a hazard, such as drought or flood, does not inherently result in a disaster. The disaster unfolds when a vulnerable community, lacking adequate coping mechanisms, suffers the impact of the hazard (Robins *et al.* 2024; van Riet 2009). Additionally, disaster risk refers to the likelihood of adverse consequences or expected losses (including deaths, injuries, property damage, livelihoods, disruptions in economic activity, or environmental harm) arising from interactions between natural or human-induced hazards and vulnerable conditions (UNISDR 2004:6).

Infrastructure disaster funding, also referred to as disaster risk financing, refers to financial assistance provided by governments or other entities to repair, rebuild, or mitigate damage caused by natural or man-made disasters to essential infrastructure systems such as roads, bridges, utilities, schools, hospitals, and public buildings (Maher *et al.* 2023).

The intensity and vulnerability to climate-induced disasters, particularly droughts and floods have increased throughout the globe with the Global South experiencing more

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(Mustak 2022). 265 million people were affected due to heightened disaster risk over 2008 and 2018. The intensity and recurrence of these disasters began escalating in the early 1980s, consistently undermining livelihoods and development (Kamara *et al.* 2018). This trend is anticipated to persist due to rapid urbanization and climate change factors expected to amplify both the frequency and severity of disasters (Culwick 2019).

2 BACKGROUND

The landscape of infrastructure disaster funding in post-apartheid South Africa is deeply influenced by the country's evolving political dynamics. Since the end of apartheid, South Africa has experienced significant shifts in its political landscape, marked by transitions in leadership, changes in government policies, and shifts in societal priorities. As a result, the approach to disaster risk management has become closely intertwined with these political changes van Riet, G. (2020), in reference to Pelling and Holloway (2006). This relationship suggests that the strategies and priorities in disaster risk management are not static but rather reflect the evolving political context of post-apartheid South Africa. The way disaster risk is managed in South Africa reflects both the changes and continuities in the political landscape.

South Africa operates as a unitary state with three distinct spheres of government that function both independently and collaboratively. The country's Constitution, along with respective and relevant legislation, delineates the allocation of powers and specifies functions that are either the sole responsibility of one sphere or are jointly managed by the multiple spheres (Maher et al. 2023). This implies that the government's responses to disasters, the allocation of resources for disaster management, and the implementation of policies are influenced by the prevailing political climate, as well as historical legacies and ongoing power dynamics within the country. In essence, disaster risk management in post-apartheid South Africa is not only about responding to natural hazards but also about navigating the complexities of political processes and priorities in a rapidly changing society. Disaster risk management (DRM) involves understanding hazards, reducing risks, and developing coping strategies for disaster impacts (Culwick 2019). South Africa's legislation on disaster risk reduction is highly regarded globally for its focus on prevention, mitigation, and preparedness, rather than solely on response and recovery (Botha *et al.* 2011). In contrast to this emphasis, there is a notable trend in other Southern African Development Community (SADC) countries, such as observed by Coetzee *et al.*, (2023), where there is a greater emphasis on disaster response funding over disaster risk funding. However, implementing DRM poses significant challenges within South Africa's multi-tiered governmental system.

In navigating the aftermath of apartheid, South Africa has witnessed a surge in public protests addressing various concerns, such as service delivery, student protests, and sporadic xenophobic outbreaks. These protests have led to the damage of critical development assets, including houses, schools, health facilities, roads, and other public infrastructure (Culwick, ibid). The most recent widespread protests (2021 July Unrest) resulted in the damage of both public and privately owned infrastructure, and business premises. These collective events underscore the complexity of the socio-political environment in the country, and how they have bearing on disaster risk funding and disaster management (van Riet 2020). This is in addition to natural disasters. The multifaceted nature of these challenges underscores the need for a nuanced approach in disaster risk management, reflecting the broader shifts and persistent elements within South Africa's post-apartheid governance landscape (Ruiters and Bond 2024). The South African government faced an additional challenge in disaster management with the onset of the COVID-19 pandemic, which to the opinion of many, showcased South Africa's preparedness and response capacity to disasters. For the first time in the history of the Disaster Management Act (57 of 2002), South Africa officially designated COVID-19 as an epidemiological disaster (Kunguma et al. 2021). Furthermore, the

KwaZulu-Natal provincial government declared a State of Disaster in response to incidents of social violence which took place in both KwaZulu-Natal and Gauteng provinces. Another significant State of Disaster declaration by the South African government was prompted by the energy crisis resulting from rolling blackouts implemented by the state-owned electricity provider, Eskom, although this declaration was rescinded shortly thereafter. One of the major challenges faced by Eskom, contributing to its inability to generate sufficient electricity, stems from infrastructural issues at its power stations, which have been poorly maintained (Zajda *et al.* 2023). The insufficient maintenance of infrastructure and other physical assets exacerbates the severity of disasters (Culwick 2019).

3 METHODOLOGICAL APPROACH – A SCOPING REVIEW OF LITERATURE

The paper used a scoping review approach to identify, synthesize, and analyze literature to provides a comprehensive overview and critical analysis of the current state of infrastructure funding concerning disaster mitigation and recovery efforts in South Africa. A search strategy involved three steps where step (i) involved identification of five keywords that include infrastructure, disaster funding, insurance, economic growth, and disaster management used to find literature for the study. Step (ii) involved database search through Scopus, Web of Science, Google Scholar, and PubMed using a combination of keywords and Boolean operators. Step (iii) involved inclusion criteria that focused on studies published in English other than other languages. Study selection was done in three steps. Step (i) screening process where authors screened titles and abstracts of retrieved articles to assess their relevance based on the inclusion criteria. Step (ii) included full-text review by the authors to determine their eligibility for inclusion in the scoping review, and step (iii) included relevant empirical results from which themes were extracted as findings of this study. Data from selected policy documents, reports, and literature relevant to infrastructure disaster funding yielded two broad themes. Thus, the paper presents two broad findings as themes related to funding mechanisms for disaster-related infrastructure across both the private and public sectors in South Africa.

4 FINDINGS ON THE LANDSCAPE OF DISASTER FUNDING IN SOUTH AFRICA

The study outlines prevalent trends in funding allocation strategies, and highlights the challenges faced in financing infrastructure for disaster prevention, mitigation, and post-disaster recovery.

4.1 *Prevalent trends in disaster funding allocation/strategies*

As mandated by legislation, disaster funding in South Africa is governed by the Division of Revenue Bill, which is commonly referred to as the Division of Revenue Act (DORA), which mandates annual approval by Parliament. This funding framework includes equitable shares or grants, distributed based on a periodically revised formula that accounts for the size of vulnerable populations within local governments and their ability to finance essential services for this demographic (Division of Revenue Bill, Act No. 5 of 2023). Grants are designed for specific purposes, with conditional grants addressing narrow objectives and unconditional grants offering broader budgetary support. Importantly, two types of grants with clear disaster response mandates exist to finance responses at the municipal and provincial levels, respectively (Maher *et al.* 2023).

Furthermore, the National Treasury of South Africa utilizes various budgetary mechanisms to facilitate the allocation of funds for disaster response. One such mechanism is virements, which allow government departments to reallocate up to 8 percent of funds originally allocated for a specific budget line item to support disaster response efforts (Gethe *et al.* 2023). Another method involves adjustment budgets, which provide flexibility by allocating additional funds to a budget line following a significant shock (Division of Revenue Bill, Act No. 5 of 2023). Additionally, agency cash flow adjustments enable departments to expedite spending by compressing a year's funding into a shorter timeframe to address emergencies, with the assurance that subsequent months in the budget cycle will be covered by an adjustment budget (Maher *et al.* 2023; National Treasury 2023).

At the national level, South Africa maintains a contingency reserve, typically allotted an annual sum of around R5 billion (Maher *et al.* 2023). This reserve serves as a tool for the government to address various unexpected financial needs, including disasters, without requiring prior approval from Parliament for significant reallocations or additional expenditure via adjustment budgets (Division of Revenue Bill, Act No. 5 of 2023). However, it's important to note that the reserve isn't specifically designated for disasters and is often utilized to support other budgetary commitments, such as assisting state-owned enterprises or covering the public wage bill (Son *et al.* 2024; Maher *et al.* 2023). For instance, in 2019, utility provider Eskom received financial support from this fund. Similar assistance has also been extended to other entities like South African Airways and the public broadcasting agency (Son *et al.*, ibid).

Administered by the National Disaster Management Centre (NDMC) under the Department of Cooperative Governance and Traditional Affairs (2016), there are two emergency funds: the Provincial Disaster Grant and the Municipal Disaster Grant. Introduced in the 2011 government financial year, their primary aim is to swiftly address immediate needs post-disaster, thereby lessening its impact. The Provincial Disaster Grant targets provincial infrastructure damages, while the Municipal Disaster Grant focuses on municipal infrastructure. Both grants, managed in conjunction with the National Treasury, are exclusively earmarked for addressing immediate post-disaster requirements to mitigate its immediate consequences. These funds, drawn from the government's contingency reserve, must be utilized within three months of allocation. Conversely, the Recovery Grant is incorporated into the standard annual budgeting process (van Niekerk 2014).

Disaster relief funding is based on assessments of specific damage from disasters. Where disaster relief funding is disbursed in terms of a conditional grant, the relevant accounting officer, and the relevant receiving officer (province or municipality) are obligated to comply with grant conditions in terms of the Division of Revenue Bill, Act No. 5 of 2023.

Lastly, South Africa has a significant history of political violence and protest actions, which continue to be common in democratic South Africa as citizens advocate for political freedom and equality (van Riet 2020). To address the risks associated with these events, South Africa established an insurance company, the South African Special Risk Insurance Association (SASRIA) which was founded following the 1976 Soweto uprising, which led to an uptick in politically motivated protests across the country (Smart 2019). While SASRIA primarily focuses on providing insurance as the sole insurer authorized to provide insurance coverage for human-caused risks, including civil commotion, public disorder, strikes, riots, and terrorism, its role in disaster response is limited (Maher *et al.* 2023).

4.2 *Challenges in financing infrastructure for disaster prevention, mitigation and post-disaster recovery*

Achieving an effective reduction in the impact of disasters (in South Africa) often necessitates the involvement of resources overseen by all levels and departments of government, as incidents can evolve dynamically, traversing various jurisdictions from local to widespread scales (Cutter *et al.* 2015). In South Africa, as with other countries in the global south, this undertaking occurs amidst the broader context of the government simultaneously addressing post-apartheid developmental hurdles and managing disaster risks, which disproportionately impact marginalized populations vulnerable to poverty and inequality (Coetzee *et al.* 2023). Moreover, these efforts unfold against the backdrop of fiscal limitations stemming from sluggish economic growth and escalating debt levels within the government (National Treasury 2023).

One of the glaring and fundamental challenges with disaster management in South Africa is that several factors contribute to disaster risk, including everyday risks such as healthcare, housing, and roads, which fall outside the jurisdiction of disaster risk departments. Consequently, disaster management departments often prioritize areas where they have direct control, such as disaster response, rather than other aspects of disaster risk management like prevention and mitigation (Maher *et al.* 2023). Additionally, political will plays a significant role in shaping disaster management strategies, with a tendency for stronger emphasis on disaster response compared to proactive development planning as politicians are more interested in "politically visible" undertakings which voters can visibly witness (Cutter *et al.* 2015; Coetzee *et al.* 2023).

There also has been a notable decline in service delivery across South Africa, particularly within municipalities (Coetzee *et al.* 2023). This decline has led to certain grants being underutilized for their intended purposes, resulting in insufficient or inadequate disaster mitigation strategies. For instance, the Provincial Roads Maintenance Grant is specifically allocated to supplement provincial investments for road infrastructure maintenance, including routine, periodic, and special maintenance tasks. Its objectives encompass addressing road damage caused by unforeseen incidents such as natural disasters (DORA, Act 5 of 2023). However, South African roads often display numerous potholes due to factors that include insufficient maintenance and climate-related damages, significantly impacting disaster risk mitigation efforts. Furthermore, these road conditions have secondary effects on the economy by impeding the efficient transportation of goods and people (Coetzee *et al.* 2023).

The stringent criteria and specific conditions attached to the two emergency relief grants pose challenges for municipalities seeking to qualify for them. In an interview conducted by Maher *et al.*, (2023), municipal officials expressed reluctance to apply for these grants due to the intricate application and implementation procedures unique to disaster grants, as well as concerns about personal liability in case of unintended misconduct. Additionally, respondents noted that the grants' effectiveness as rapid response tools are compromised by complex assessment procedures and delays in disbursements, stemming from municipalities having to demonstrate their inability to respond using their own resources.

Apart from disasters planned for by government, in recent years, South Africa has witnessed a rise in public protests for issues such as service delivery, student protests, and occasional xenophobic outbreaks. Social unrest in present-day South Africa may manifest as a disaster, serve as an indication of underlying vulnerabilities or impending disasters, or represent a combination of both scenarios (Mkwakwami *et al.* 2019). Predicting social phenomena poses challenges, leaving SASRIA susceptible to shocks. Over the past five years, service delivery protests have been the primary catalyst for claims, comprising 80 percent of total claims, with labour strikes making up the remainder (Smart 2019; Maher *et al.* 2023). This excludes damages due to student protests.

With the contingency reserve, the flexibility afforded by the contingency reserve provides the National Treasury with discretion in allocating funds. Nevertheless, this approach presents certain challenges. Firstly, it may foster the expectation within government departments that they are entitled to resources from the reserve, potentially resulting in numerous requests to the National Treasury for access (Maher *et al.* 2023). This influx of demands can overwhelmingly be above the available resources and pose political difficulties in management (Coetzee *et al.* 2023). Moreover, if the contingency reserve is depleted early in the budget cycle, it leaves the National Treasury and the budget vulnerable to the financial repercussions of unforeseen events.

5 CONCLUSION & RECOMMENDATION

These findings of this paper show that the Government of South Africa, particularly the National Treasury, has established a robust framework for financing disaster risk and response. This framework relies on the following main components: (i) a risk-layering strategy implemented by the National Treasury for financing disaster response, and (ii) National Treasury's commitment to transparency and openness in budget preparation, enhancing the credibility of the budget and facilitating access to financing.

The paper also reveals numerous challenges in infrastructure disaster funding in South Africa, hindering the government's ability to effectively manage disasters. While disaster risk reduction (DRR) investments are essential for mitigating risks and impacts, interventions focusing on long-term mitigation activities often receive inadequate funding compared to humanitarian assistance, relief efforts, and post-disaster reconstruction, as demonstrated in this paper.

Despite the South African government's efforts in planning, policy development, and legislation for disaster risk mitigation and response, significant barriers hinder successful implementation. These include funding shortages, bureaucratic complexities in accessing disaster response funds, and insufficient infrastructure maintenance. Consequently, there's a need for increased investment in human resources and exploration of alternative funding sources for disaster response beyond fiscal revenue. Private capital markets could play a role in bolstering disaster resilience (Leitner *et al.* 2018; Stewart *et al.* 2009).

Lastly, advocacy efforts are necessary to change the strategies and practices of politicians as heads and leaders of government, and senior officials toward disaster risk reduction, as these decision-makers significantly influence policy and budget allocation for disaster risk funding. This shift in strategy and approach can bridge the gap between disaster risk reduction and development, contributing to poverty eradication and reduced inequality. Investments in mitigation, preparedness, and resilience are crucial, as they ultimately lead to lower response costs in future disasters. Disaster resilience needs to be treated as a long-term strategy to mitigate the devastating effects of recurring disasters, particularly in the context of the ongoing and recurrent challenges posed by climate change.

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Exploring the socio-economic transformation in post-apartheid South Africa: Lessons from Cosmo City mixed housing development

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ABSTRACT: Since the beginning of the 21st century, many developing countries in the global south have been experiencing high levels of urbanisation. This led to the transformation of cities into economic hubs that shape cultural and social life. In South Africa, there are several interventions to address the impact of urbanisation and apartheid's spatial injustices. This paper investigated the impact of these interventions on Johannesburg's social and economic transformation, focusing on Cosmo City Township. Using a qualitative case study approach, data was collected through resident questionnaires and interviews with municipal officials. A qualitative approach was chosen to understand the residents' and municipal officials' experiences and perceptions. The results showed that Cosmo City's mixed housing development has, to some extent, influenced social and economic benefits to the residents. However, these benefits have not been translated to the broader communities as the newly constructed housing has not been accessible to everyone.

Keywords: Socio-economic transformation, Mixed housing development, Cosmo City, Johannesburg

1 INTRODUCTION

Several developing countries, particularly in the Global South, have been experiencing high rates of urbanisation since the beginning of the 21st century. This urbanisation marked a shift in the demographic patterns and the spatial dynamics of cities (Cohen 2006; Cividino *et al.* 2020; Dyson 2011). As these cities grow, they continuously evolve into vital hubs that promote economic growth (Glaeser and Steinberg 2018; Forte 2019) and cultural vibrancy (Levickaitė 2011). However, due to rapidly urbanising, these cities also encounter many challenges such as infrastructural constraints, housing shortages, and socioeconomic inequalities (Aliyu and Amadu 2017; Ejaro and Abubakar 2013), resulting in challenged city spaces. Amid these challenges, the dynamic characteristics of urbanisation need an in-depth examination that demonstrates how Cosmo City, built in the historical context of apartheid's demise functions as a microcosm of the larger initiatives to reshape South Africa's urban landscape.

Established in the early 2000s, the Cosmo City mixed housing development was proposed as a deliberate exodus from the segregationist policies of the past, determined to create an integrated community characterised by diverse housing options and economic inclusivity (Haferburg 2013; Onatu 2010). Cosmo City's spatial and socioeconomic transformation reflected the difficult choices made in balancing societal objectives, historical legacies, and the challenges of urban development. The vision for Cosmo City was rooted in inclusivity, envisioning a harmonious coexistence of individuals from diverse racial, ethnic, and economic backgrounds within the same community (Onatu 2010). The neighbourhood layout was carefully planned to avoid the spatial segregation that characterised the apartheid era's

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segregationist planning, providing residents with various housing options and promoting a sense of social cohesion. At first, Cosmo City was praised as a symbol of the country's will to promote unity and eradicate the legacy of apartheid, as well as a beacon for progress and an effective urban transformation (Onatu 2012).

Despite the early promises of this flagship project, it is now faced with many challenges. The hard realities of urban development have shattered the initial hopes that Cosmo City would promote unity among citizens. The neighbourhood struggles to maintain its original vision of bringing people from different racial, ethnic and income groups together. As the population continues to grow and mature, Cosmo City is now faced with many challenges that divert it from its original vision. The challenges include infrastructural strain, inadequate public services, and the emergence of economic disparities within the community, which pose significant challenges for this community. The initial objective of establishing an interconnected community has encountered challenges exposing the complexities and difficulties involved in transforming urban planning into long-lasting social realities.

These unique challenges are faced by many cities in the Global South. An investigation into Cosmo City's experiences will contribute to the complex dynamics that shape urban spaces in the aftermath of historical injustices. Through an examination of the spatial and socio-economic transformations that have occurred within the context of this mixed housing development, the study aims to provide insightful information that may be applied to other urban environments facing similar challenges. By doing this, this paper intends to further dialogues on social integration, resilient communities, and sustainable urban development in the post-apartheid era and beyond. As an illustration of the broader narrative of urban development in the post-apartheid era, this study examines the instance of Cosmo City, which is located outside of Johannesburg, South Africa.

2 LITERATURE REVIEW

South Africa's journey from apartheid to democracy marks one of modern history's most significant political transitions. The apartheid system, implemented from 1948 to 1994, was characterized by institutionalised racial segregation and discrimination, profoundly shaping the country's social, economic, and political landscape (Molope 2022). Under apartheid, non-white South Africans faced systemic oppression, forced removals, and limited access to fundamental rights and opportunities. In the transition to democracy, South Africa underwent significant socioeconomic transformations to address the deep-rooted inequalities created by past discriminatory policies. One of the most important initiatives in this regard has been the development of mixed housing projects to create integrated communities where people from different socio-economic backgrounds can live together.

As Williams (2000) highlights, transformation is central to South Africa's social change. But what does 'transformation' mean in South Africa's complex socio-political landscape? Mbembe (2008) defines transformation as a comprehensive set of policies and initiatives to rectify historical injustices resulting from apartheid-era racial discrimination. It encompasses government and private sector efforts to redistribute wealth and income to previously disadvantaged groups, mainly black South Africans. This process integrates moral imperatives of justice and equality with pragmatic considerations of power dynamics and social engineering, reflecting the challenge of dismantling entrenched racial hierarchies. Ultimately, transformation represents a fundamental attempt to overcome the enduring legacy of apartheid and transcend racial categorizations in contemporary South African society.

From a historical-sociological perspective, "societal transformations are a type of social change that should be understood as an alternative to traditional modes of formation such as the formation of modern democratic and capitalist societies" (Castles 2001). Social transformation refers to long-term societal shifts on a deep structural level. Therefore, the most visible forms of change are not necessarily the most profound ones. Social change only counts as a transformation if it reflects deeper forms of change on the level of value systems and power structures (Castles 2010). Social transformation refers to a macro-level fundamental change in society's deep structures and organization, affecting all dimensions of social life (Sewell 2005). Socioeconomic transformation within the context of South Africa expands the notion of transformation to include a specific focus on economic and social dimensions. It entails comprehensive changes in economic structures, distribution systems, and social policies to foster equitable growth, reduce disparities, and promote inclusive development. Socioeconomic transformation builds upon the broader transformation agenda, emphasising the need to address economic inequalities, create opportunities for marginalised communities, and ensure sustainable livelihoods for all citizens. Despite progress, socioeconomic transformation in South Africa faces numerous challenges. Persistent inequalities, high unemployment rates, and spatial disparities continue to hinder inclusive development (Huchzermeyer 2011). Moreover, corruption, governance inefficiencies, and policy implementation gaps pose significant obstacles to achieving transformative goals (Charlton and Kihato 2010).

2.1 *Socio-economic transformation in post-apartheid cities*

Socio-economic transformation in the post-apartheid South Africa is a process that is characterised by significant progress, ongoing challenges, and persistent inequalities (Chipungu and Zungu 2019). This is to say there is notable progress in the efforts of rectifying the past injustices. This is in the form of policies and initiatives such as the development of new mixed housing developments throughout the country. However, even with the efforts directed towards addressing the past injustices, the legacy of the apartheid policies is still visible in the country social and economic structures. There is high income inequality, whereby the majority of the country's wealth is still in the hands of a few people. As the World Bank highlights (cited in Greenwood 2018), South Africa is the most unequal country in the world and its poverty is enduring the legacy of apartheid. The majority of the people in the country are still highly marginalised, facing high levels of poverty and unemployment. Urbanisation is another challenge that the country is facing. The population rapidly urbanised that in 2017, 65,85% of population was living in urban areas (Statistica 2018). With this rapid migration, cities in the country faced challenges in providing enough housing to accommodate the urban population, leading to the proliferation of informal settlements and urban sprawl.

In an attempt to address these challenges, the post-apartheid government implemented Housing Subsidy programs, which allowed low- and middle-income households to purchase affordable housing. Though the policies' building pace was excellent, and homeownership was commendable, it was unable to keep up with the massive demand for high-quality, large-scale homes. The social and spatial legacies of apartheid's "social engineering" in South African cities were not addressed by this approach. In post-apartheid cities, little has been done to change the spatial segregation and fragmentation that characterized apartheid. Rather, an oversimplified "supply side" strategy has been used, which ignores the more significant geographical and social problems that remain from apartheid. In post-apartheid neighbourhoods, mixed-income housing developments are viewed as a creative way to address these issues and encourage social cohesion. It is thought that mixed-income housing can offer a range of housing options appropriate for diverse income brackets, thus contributing to the overall transformation of post-apartheid cities. Efforts are currently being made to explore the possibilities for creating more effective policy frameworks in post-apartheid cities to address the housing backlog as well as the social and spatial legacies of apartheid.

3 STUDY AREA

The spatial scope of this study incorporated Johannesburg and was limited to the Cosmo City area. The Cosmo City Mixed Housing Development holds particular significance as a microcosm of South Africa's post-apartheid urban landscape. Situated on the outskirts of Johannesburg, Cosmo City emerged as a response to the dual challenges of housing shortages and spatial segregation inherited from the apartheid era. Its size is approximately 1105 hectares. It is located on Malibongwe Drive between Randburg and Lanseria Airport. It is marketed as the best-located affordable housing in Johannesburg's north-western side (Haferburg 2013), with proximity to Randburg, Midrand, Roodepoort, Sandton, and the CBD. The development embodies the principles of mixed-income housing, aiming to create integrated communities where residents from diverse socio-economic backgrounds live side by side. Cosmo City's significance lies in its potential to address multiple dimensions of socio-economic transformation. Through the provision of affordable housing options, access to amenities, and opportunities for social interaction, the development sought to break down barriers of race and class, fostering greater social cohesion and economic empowerment.

4 RESEARCH METHODS

The study adopted a qualitative approach to fully explore the question "To what extent have the spatial developments influenced the socio-economic transformation in Cosmo City in the City of Johannesburg?". A qualitative case study approach was chosen to extract meaning from the experiences of residents living in the Cosmo City area of Johannesburg. Throughout the research, interviews were conducted with a series of municipal officials and external stakeholders. Five (5) municipal officials and three (3) external stakeholders were interviewed. Thirty (30) questionnaires were sent to community members of Cosmo City who have been residing in the area for at least ten years. Observations and literature were also used to support the information gathered using interviews and questionnaires. The convenience sampling method was used to select respondents (municipal officials) involved in planning spatial transformation and those who design policies to reduce inequality and promote inclusiveness within the City of Johannesburg. Key municipal officials were targeted for these interviews so that they could give expert perspectives on spatial transformation initiatives and possible outcomes concerning socioeconomic transformation. Convenience sampling was also used to select external stakeholders from the private sector who were also involved in the planning and development of Cosmo City. Purposive sampling was conducted to choose participants who resided within the City of Johannesburg's Cosmo City area for at least ten years. These participants were chosen because they would provide a historical perspective on changes that have occurred in Cosmo City by comparing the past and the current state of socioeconomic status. These residents were able to identify the social and economic changes that have occurred in the area. The primary and secondary data were used to give the researcher a better understanding of the status quo of the socio-economic transformation within Cosmo City. The paper adopted qualitative content analysis to analyse the data collected. From the interviews conducted, questionnaires and literature reviewed, the author identified recurring themes and insights related to the impact of the developments of social and economic transformation in the area. From the themes identified, the findings were interpreted in relation to urban development, spatial transformation and socioeconomic transformation.

5 THE SOCIO-ECONOMIC DYNAMICS OF COSMO CITY

The project in Cosmo City is a good case study in the broader context of post-apartheid South Africa. It shed light on what is happening in terms of socio-economic transformation in post-apartheid cities. This project is at the centre of the multifaceted network of South Africa's socio-political landscape, offering a lens through which to study the complex interactions between urban planning initiatives, housing policies, and community dynamics.

Through an in-depth investigation of this development, the study reveals the complex nature of social and economic transformation and provides insightful information about the challenges, achievements, and lessons learned in the pursuit of inclusive and equitable urban development in the post-apartheid era.

5.1 *Affordability*

One of the pivotal aspects of transformation in South Africa is the increased housing affordability within the communities. Historically, apartheid policies relegated certain populations to marginalized areas, perpetuating socio-economic disparities. The intentional development of mixed housing in Cosmo City represented a departure from this legacy, fostering inclusivity and affordability by providing a spectrum of housing options (Onatu 2010; Ruiter 2009; Simbanegavi 2019). This departure signified a significant shift in urban planning philosophy, emphasizing the importance of creating integrated communities where residents can access suitable affordable housing regardless of their economic background.

Affordability had broader implications for social cohesion and economic resilience in the area. The project in Cosmo City accommodated residents from different income groups, thus making the community economically diverse, which helped to foster a more resilient local economy. From the data collected, more residents indicated that this project enabled them to access various housing options that suit their financial capacities, creating a socio-economic tapestry that reflects the country's diversity. Through the diverse housing options, Cosmo City has facilitated the integration of individuals from various socio-economic backgrounds, creating a vibrant and inclusive community representative of South Africa's diverse population. This integration contributed to the larger objective of creating a more cohesive and equitable society by fostering possibilities for mutual understanding and cooperation among citizens as well as improving social cohesiveness.

The most noticeable positive outcome of this flagship project is an increase in housing affordability. However, it is also important to acknowledge that not all residents have benefited equally from this project. Some community members still struggle to afford the housing units in this project. Some residents are still unable to afford to live in these newly built housing units because of high rental prices which remain out of reach for those with lower incomes. This unaffordability can be seen in the growth of backyard shacks, informal settlements, and vacant housing units in Cosmo City. The reality is that while the mixed housing development creates opportunities for many to access affordable housing, it exacerbates the exclusion of residents, particularly those on the lower end of the income spectrum.

Recognizing that not all residents can afford housing in this mixed development project, targeted financial assistance programs should be designed to help low-income individuals and families. This can take the form of grants, or low-interest loans to help pay for housing and facilitate access to affordable housing. In Cosmo City, this financial assistance was in the form of the Financed Linked Individual Subsidy Programme (FLISP), which is aimed at assisting people who fall into the "Gap Market" because they either earn too much to qualify for an RDP house or earn too little to qualify for a home loan from the banks. However, this assistance is only for people who have intentions to purchase houses. Thus, more assistance could be extended to include rental subsidies or vouchers for low-income individuals and families who may not be in a position to purchase a house but still require affordable housing options.

5.2 *Household stability*

Cavanagh and Fomby (2019) define household stability as the ability of a household to maintain a consistent and secure living environment over time. This is important for the well-being of individuals, families, and society as it provides a foundation for growth, resilience, and prosperity, contributing to healthier and more vibrant communities. Jelleyman and Spencer (2008) highlight instability in households as an aspect that brings emotional problems, teenage pregnancy, use of illegal drugs, reduced continuity of care, and depression. Thus, instability is classified as a driver of social inequality in communities. In Cosmo City, affordable housing has been noted to have had a good impact on giving stability to poor and middle-income groups. This was achieved by lowering the rent burden, which led to an improvement in the household's financial situation. Participants in the study indicated that rent prices since the development of mixed housing have been affordable. Out of the thirty participants who took the questionnaire, nineteen of them indicated that the rental prices were more affordable after the implementation of the mixed housing project. This can be attributed to the introduction of affordable housing options in the project and the increase in availability of housing units which led to competition amongst the owners, further driving down rental prices in the area.

5.3 *Community cohesion*

Mixed housing programs frequently address the issue of socioeconomic mixing, also known as social mix, which comprises cultivating socially varied neighbourhoods. Housing is thought to play a substantial effect on both social mix and poverty de-concentration. For a variety of reasons, including increasing the socioeconomic well-being of low-income households, deconcentrating poverty, and renewing the status of public housing, income mix is promoted. The City of Johannesburg has highlighted social mix as a "requisite for sustainable development". It is a means to enable people to stay in their neighbourhoods to preserve a sustainable community and a strategy to avoid social segregation and break the cycle of apartheid policies that aimed at segregating people based solely on their race. Litman (2011) noted that legislation that supports affordability and accessibility within a society is "the polar opposite of gentrification: it permits households with a wide range of incomes, skills, and needs to coexist in beautiful, varied, and lively neighbourhoods". The City of Johannesburg set proportionate targets for affordable housing in its Inclusionary Housing Strategy in 2005 with the goals of "promoting social mix," "facilitating the building of social and communal housing," and stimulating the creation of private cheap ownership units.

In post-apartheid South Africa, community cohesion plays a critical role in the country's efforts to achieve socioeconomic transformation. It is essential because community cohesion fosters a sense of belonging, trust, and solidarity among diverse individuals and groups (Alam *et al.* 2016). Community cohesion allows for the establishment of trust and social unity among diverse groups within society. This is crucial in post-apartheid South Africa, which has a complex history marked by racial segregation and inequality. By fostering trust and unity, community cohesion helps to bridge the gaps between different racial, ethnic, and socioeconomic groups. It promoted social inclusion and equal participation in decision-making processes (Nel *et al.* 2001). This ensured that the voices of all community members in marginalized and underrepresented townships like Cosmo City are heard and taken into account in policy-making and development initiatives (Alam *et al.* 2016).

Despite the project's intentions of promoting social cohesion, Cosmo City is still predominantly black, with few people from other races. The lack of racial diversity in the area shows that while mixed development initiatives may address some socio-economic disparities, they may not effectively tackle underlying issues of racial segregation and integration within the community. This highlights the importance of considering broader socio-cultural factors in urban development projects to truly foster inclusive and cohesive communities. Recognizing and embracing the diversity of cultures, beliefs, and traditions in communities like Cosmo City, planners and developers can create a welcoming urban space where all people from different races, ethnicities and income groups can feel a sense of belonging.

5.4 *Access to opportunities*

The economy of South Africa is not only driven by urban regions. Townships such as Cosmo City are vital in advancing economic growth and development. Despite their historical marginalization, these areas contribute significantly to the country's economy by creating a township economy that supports broader economic activities. Township economies ensure that economic growth is not limited to cities but extends to rural and non-urban regions. The mixed housing development in Cosmo City represents this phenomenon because it provides opportunities for employment creation and economic participation within the township itself. Through local businesses and enterprises, township economies like Cosmo City offer unique experiences and rapid accessibility to goods and services tailored to the community's needs. This accessibility allows residents to access essential goods and services conveniently without the need to travel to commercial centres located outside the township. This signified a change in post-apartheid South Africa's strategies, indicating the importance of inclusive economic development strategies that prioritize the empowerment and upliftment of historically marginalized communities. Cosmo City has been an area where the informal economy thrives, which is a significant aspect of the township's socio-economic landscape. The informal economy is an economy that is unregulated by the institutions of society (Castells and Portes 1989). The development of the mixed housing units in Cosmo City led to an increased population density in the area and its surroundings. This higher population density created a larger customer base for informal businesses, including street vendors, small shops, and service providers.

South Africa grapples with a concerning youth unemployment crisis, where rates have soared to alarming levels. According to StatsSA (2016), while the overall unemployment rate in the nation has risen steadily, hitting 26.7%, the youth unemployment rate stands at an even more staggering 54.5%. This statistic underscores the urgency of addressing youth unemployment as an integral facet of broader socio-economic development transformation. The informal township economy in Cosmo City plays a significant role in mitigating the impact of youth unemployment. Many young individuals turn to informal entrepreneurship and small-scale businesses within this township to generate income and livelihoods. The informal economy offered avenues for youth to engage in entrepreneurial activities through street vending and small shops. It provided opportunities for self-employment and economic participation for the youth in the area. There is a need to encourage economic diversification and entrepreneurship within Cosmo as this will create opportunities for the local community to flourish. This can be done through supporting small businesses, startups and local businesses to spur economic growth, create jobs and provide residents from diverse backgrounds with pathways to success.

5.5 *Crime and safety*

In the context of exploring the socio-economic transformation in post-apartheid South Africa, it's crucial to consider the impact of the physical environment on crime rates, within townships like Cosmo City. Studies have indicated that the physical surroundings surrounding a development can significantly influence crime rates. Decent housing can aid in crime prevention (Nassauer and Raskin 2014). Research conducted by Trachtenberg *et al.* (2016) suggests that deliberate efforts to enhance the physical environment, such as planting high levels of greenery, can systematically reduce crime and levels of hostility and violence. Specifically, the presence of well-landscaped vegetation, such as mature trees, has been linked to a 55% reduction in crime rates compared to areas with basic, bare courtyards. This improvement in the physical environment not only contributed to a greater sense of security in Cosmo City but also reduced stress and enhanced the overall quality of life for residents. The development of the Cosmo City housing projects created a safer and more supportive environment, according to the residents.

The mixed housing strategy in Cosmo City not only addressed the socio-economic imbalances of the past but also actively contributed to the ongoing spatial transformation efforts by the city of Johannesburg and the country as a whole. The deliberate inclusion of diverse housing types has dismantled the rigid spatial divisions characteristic of apartheid-era planning. As a result, the community becomes a vibrant tapestry of various housing structures, facilitating social interaction among residents from different economic strata. It is important to acknowledge that these benefits may not be equally accessible to everyone due to affordability and income disparities. Overall, this spatial integration brought about by the Cosmo City mixed housing development project is a crucial lesson for post-apartheid South Africa, demonstrating that thoughtful urban planning can play a vital role in dismantling historical spatial injustices and creating environments where people from diverse backgrounds coexist harmoniously.

The implementation of mixed housing development in Cosmo City as part of the socio-economic transformation efforts in South Africa has had a significant impact. This mixed housing project as seen in the results above have played a significant role in fostering and promoting social integration, economic empowerment of people who rely on the informal economy and a sustainable urban development in the Johannesburg area. This initiative has not only addressed the challenges of the apartheid's historical legacy but also paved the way for an equitable and inclusive society.

6 CONCLUSION

Overall, this study has shed light on the social and economic impacts of socioeconomic transformation initiatives in Johannesburg by looking at the case study of Cosmo City Township. While the development of mixed housing in the area has brought about positive benefits for residents, such as affordability, household stability, community cohesion, improved safety and access to opportunities, challenges remain in ensuring that these benefits are equitably distributed across the community. The findings underline the importance of addressing affordability barriers and fostering community driven solutions to maximize the social and economic benefits of spatial transformation in Cosmo City. The paper recommends that initiatives must prioritize inclusivity, affordability, and community participation to ensure sustainable and equitable development outcomes for all residents. Thus, planners and policymakers need to create dynamic, inclusive, and resilient communities in Johannesburg and beyond by implementing an inclusive approach incorporating social and economic factors. Ultimately, the success of spatial transformation efforts lies in their ability to empower communities, enhance social cohesion, and promote shared prosperity for all urban residents.

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The emergent of Livingstone City: Economic transition and the built environment nexus

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ABSTRACT: Economic transitions shape the built environment's form, function, and evolution. This study explores the intricate relationship between economic transitions and the built environment of Livingstone City, influenced by its colonial past, post-colonial challenges, and recent tourism development. It investigates how economic activities that include tourism and manufacturing shape Livingstone through the need for business infrastructure and housing support. Through systematic review and visual analysis, the study provides insights into the dynamic interplay between urban landscape and economic shifts, transforming land use patterns, spatial distribution, and infrastructure. Exploring the case of Livingstone, the study suggests practical economic and physical planning lessons that may not be generalizable to other contexts but can inform urban planning and development strategies in Livingstone and similar cities. Recommendations are made for optimizing and managing socio-economic transformation in emerging new economic hubs of developing secondary African cities.

Keywords: Economic hub, Urban landscape, Built Environment, Economic Transition, Trade

1 INTRODUCTION

Cities are not static entities, but relatively dynamic organisms in constant flux, shaped by the ebb and flow of economic tides. As economic tides shift, so too does the physical landscape, leaving behind indelible imprints that whisper tales of success, deterioration, and reinvention. This intricate relationship between economic activity and urban transformation has been explored by several researchers, highlighting how changing economic landscapes inevitably leave their mark on the physical fabric of cities (Bunnell 2005; Brenner 2004; Harvey 2008). This research probes into the city's fascinating tapestry, tracing the intricate choreography of economic change and the physical response it has elicited.

With Zambia's independence in 1964, a new chapter unfolded for Livingstone. Colonial legacies were challenged, and the city embarked on a quest to forge a post-colonial identity. The physical landscape witnessed this shift, with government buildings adopting a distinct, modernist style, symbolizing a break from the past and a burgeoning sense of national pride (Simutanyi 2008). The post-colonial government's attempts to transform the country into a modernised economic society included setting-up of manufacturing and industries. One of these was the Livingstone Motor Assembly which was set up in 1970, by Kenneth Kaunda's post-colonial government it was intended to improve transportation and employment (Southall 1980). These were to become the main sources of employment for Zambia in efforts to modernise society under the new government's National Development Plans, poor management, complex

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one-sided arrangements with multinational companies, and lack of capital investment led to the demise of these industries which could not survive the Structural Adjustment Programme measures that Zambia had implemented under the IMF in the early 1990s. However, labour issues related to the casualisation of labour, poor working conditions and low wages in the large tourism industry, unequal distribution of resources, and municipal service delivery especially in the peri-urban settlement are almost non-existent, and the Livingstone Integrated Development Plan remain unimplemented (Phiri 2021). The colonial infrastructure has remained in the form of urban informal settlements, a constant reminder of a bygone era, while pockets of under-development emerged within its confines, showing the unfulfilled promise of independence. Livingstone's infrastructure and spatial development remain largely unattained. Instead, what results is illogical and mixed piecemeal developments largely informal and sporadic that add little to the identity and character of the City of Livingstone.

This study comprehensively analyses the intricate relationship between the built environment and economic transitions in Livingstone, with a focus on understanding the future prospects, current dynamics, and historical trajectories. Unlike prior studies on broader areas or larger cities, this research focuses on a specific secondary African city. Recommendations are then proffered, fostering sustainable and inclusive urban development for emerging new economic hubs in developing secondary African cities.

2 LITERATURE REVIEW

Cities are dynamic entities, constantly evolving in response to economic, social, and political forces. This literature review probes into this dynamic nexus, examining how economic changes influence infrastructure, land-use patterns, and the overall trajectory of urban development.

2.1 *Economic transitions and infrastructural transformations*

Harvey (1973) and Brenner (2004) argue that economic systems influence urban infrastructures through processes of capital accumulation and spatial restructuring. These shifts are often manifested in the development of new infrastructure like transportation networks, energy grids, and communication systems, designed to facilitate the flow of goods, services, and capital. In the case of Livingstone, the colonial era's resource-extraction economy led to the construction of the railway line connecting Livingstone to the wider colonial network, solidifying its role as a trading hub (Ng'ombe 2017). Similarly, the post-independence focusses on national development saw the construction of government buildings in a distinctly modernist style, symbolizing the break from colonial influence and the hope for a positive future (Simutanyi 2008).

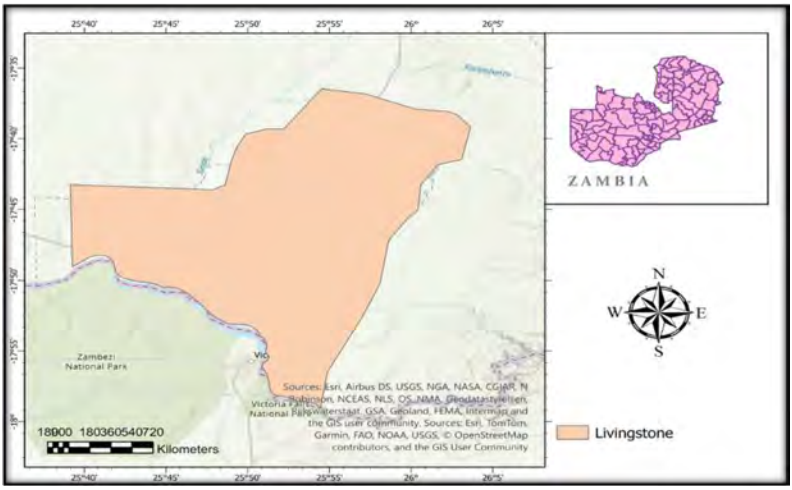
2.2 *Land use patterns and economic restructuring*

Land use patterns within cities are also heavily influenced by economic changes. Castells (1978) and Sassen (2001) highlight how economic shifts can lead to the spatial segregation of different social classes and economic activities. In Livingstone, the rise of tourism in the late 20th century spurred the development of hotels and tourism-related infrastructure along the Zambezi River, displacing existing communities and creating a distinct tourist zone separate from the rest of the city (Crush and Grainger 2005). This spatial segregation further exacerbated existing inequalities, highlighting the need for balanced and inclusive urban development strategies.

2.3 *New Urban Agenda*

The New Urban Agenda (NUA), adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in 2016, provides a valuable framework for analyzing Livingstone City's economic transition (UN-Habitat 2016). The NUA emphasizes the importance of inclusive and sustainable urbanization, focussing on creating cities that are prosperous, equitable, low-carbon, and resilient (C40 Knowledge Hub, https://www.c40knowledgehub.org/s/). The study aligns with the NUA's objectives by examining how Livingstone's economic transformation is shaping its built environment, with particular attention to the need for inclusive housing development strategies. By ensuring that the city's economic growth benefits all dwellers and contributes to a sustainable urban future, Livingstone can achieve the goals outlined in the New Urban Agenda. The literature review demonstrates that economic transitions have a profound impact on the built environment, shaping infrastructure, land use patterns, and the overall trajectory of urban development. Livingstone, with its colonial legacy, post-independence struggles, and recent focus on tourism, offers a compelling case study for exploring this dynamic nexus.

3 EMPIRICAL SETTING



Map 1. Livingstone. Source: Mhlalisi Mndzebele (2024).

Map 1 depicts the location of Livingstone, a vibrant city situated on the banks of the Zambezi River in Zambia, offers a convincing case study for exploring this dynamic nexus. From its humble beginnings as a colonial outpost to its contemporary incarnation as a bustling tourist hub and gateway to Victoria Falls, Livingstone's physical fabric bears the permanent marks of economic transitions, providing a rich image for understanding the interplay between economics and urban spaces.

4 METHODOLOGY

Cities across the globe are subject to continuous change influenced by economic activities, and Livingstone City is no exception. This inquiry unravels the nexus between economic transition and the built environment in Livingstone City, employing a methodology that relies on the systematic review and analysis of visual representations. An extensive search was conducted across multiple academic databases, including Google Scholar, JSTOR, and

Scopus, using keywords that include “economic transition,” “built environment,” and “Livingstone City.” The search initially identified 1500 documents, which were screened through a two-step process involving title and abstract review followed by full-text assessment. This rigorous selection process, guided by inclusion and exclusion criteria, narrowed the pool to 35 high-quality and relevant studies. The criteria ensured the inclusion of peer-reviewed articles published between 2000 and 2023, focusing specifically on the impact of economic transitions on urban development. This is further demonstrated in Figure 1 below.

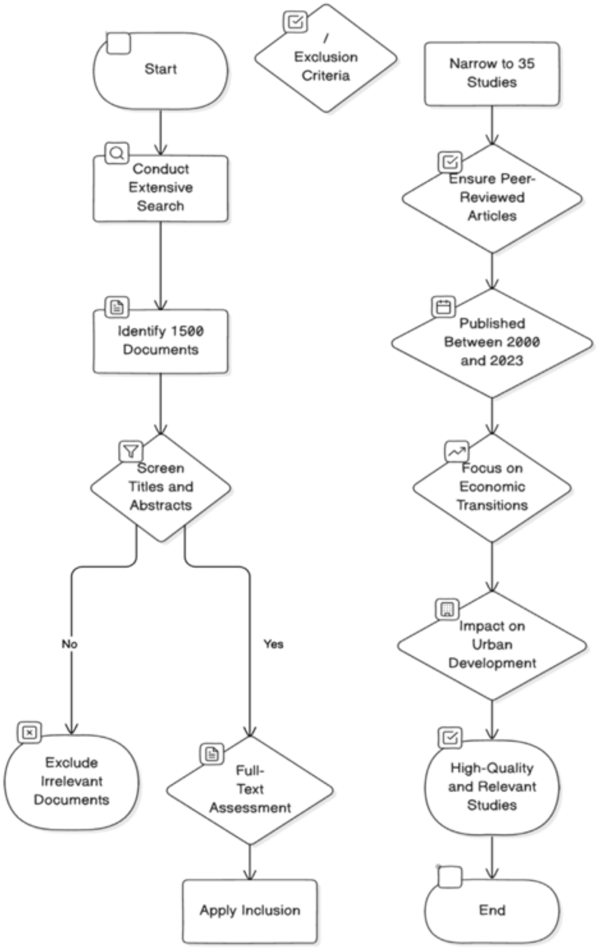


Figure 1. Research methodology. Source: Mhlalisi Mndzebele (2023).

Data extraction from these studies was systematic, categorizing findings into themes of infrastructural transformations, land use patterns, and housing challenges. The quality of the selected literature was assessed based on methodological rigor, clarity of findings, and relevance to the research questions. Visual tools such as aerial photographs, and GIS data were used to illustrate changes in the city’s infrastructure and layout. The findings were contextualized within broader urban development frameworks of the New Urban Agenda and Sustainable Development Goals, ensuring alignment with global urban sustainability principles.

5 FINDINGS AND DISCUSSIONS

The emergence of Livingstone City symbolizes a significant case study in the interpretation of the complex relationship between economic transitions and the built environment. Through a pragmatic approach and comprehensive review of pertinent literature, the study explored various dimensions including infrastructural transformations and economic transitions, housing challenges, land use patterns, and economic restructuring, along with urban development. The analysis revealed several key findings, shedding light on the complex interplay between economic shifts and the built environment.

4.1 *Infrastructure changes*

Figure 2. Shopping Centre Intercity Bus Terminus Hotels
Source: Saidi Finzi (2023).

Economic transitions necessitated investments in transportation, utilities, and communication networks to support burgeoning economic activities. Consequently, as shown in Figure 2, Livingstone City witnessed the expansion and modernization of infrastructure, aimed at enhancing connectivity and facilitating economic growth. However, disparities in infrastructure provision across different areas of the city underscored persistent challenges in ensuring equitable development.

4.2 *Spatial distribution of economic activities*

Figure 3. Informal street trading zones. Source: Saidi Finzi (2023).

The study documented the spatial reconfiguration of different economic activities of informal trading within Livingstone City as depicted in Figure 3. As economic priorities shifted, certain areas experienced concentrated development while others underwent a decline. This is apparent in Figure 3 as compromised building materials are used to build shelters for informal trading activities within different zones. Furthermore, these zones are not provided with drainage systems and paving passages (See Figure 3). Gamieldien and Niekerk (2017) indicated that numerous traders face health risks because they lack shelter and are exposed to weather elements. Despite these challenges, Fourie (2018) affirms that the informal economy plays a vital role in reducing poverty since the income generated from informal trade flows to poor households. Conversely, the challenges faced by informal street traders in Livingstone City are associated with disinvestment and social marginalization, highlighting the spatial inequalities inherent in urban economic transitions.

4.3 *Housing challenges*

Housing is identified as a critical issue intersecting with economic transitions in Livingstone City. Figure 4 shows the morphology of the Malota informal settlement characterized by narrow lanes and irregular access networks. Informal settlements proliferated on the outskirts of the city, reflecting the inadequacy of formal housing provisions to meet the needs of a growing population.

Figure 4. Morphology of Malota informal settlement. Source: Mhlalisi Mndzebele (2023).

The dwellers of these urban informal settlements in Livingstone City are exposed to poor sanitation, environmental, and living conditions due to inadequate municipal services (Phiri 2021). Rapid urbanization, driven by economic opportunities, exerted pressure on housing markets, leading to affordable housing challenges and spatial segregation. Addressing these housing challenges requires holistic approaches that integrate social, economic, and environmental considerations.

4.4 *Urban development and land use patterns*

One of the central findings of the study pertains to the transformation of land use patterns driven by economic restructuring. This transition has had profound implications for land use, with former agricultural areas being repurposed for commercial and recreational purposes. The developments in the form of new attractions, services, and facilities such as hotels pressure the environmental resources (Liu and Mwanza 2014). While the initial surge in tourism led to job creation and increased revenue, the environmental consequences of mass tourism raised concerns about long-term sustainability. Tourism stands as the fastest-growing industry globally, boasting a tourism business worth 3 trillion dollars (World Travel and Tourism Council 2017). However, embracing the concept of tourism is equally important, which refers to the low impact on the environment and local culture while helping to generate future employment for local people (Javed and Tučková 2018).

5 TOWARDS OPTIMIZATION OF EMERGING NEW ECONOMIC HUBS IN DEVELOPING SECONDARY AFRICAN CITIES

Building on the findings of this study, several recommendations are proposed aimed at encouraging sustainable urban development in Livingstone City and other similar contexts.

Given the interplay between the built environment and economic transitions, there is a pressing need for integrated urban planning approaches that consider the multi-layered dimensions of urban development. Discoveries about changes in land use patterns as a result of pressures from new developments that threaten environmental resources require prioritization of principles that integrate land use planning, infrastructure development, and housing policies to foster resilient and inclusive urban landscapes (Brown and White 2019). These principles are inspired by NUA which emphasizes the importance of sustainable urban planning to address the complex challenges facing urban areas, including economic transitions and environmental sustainability (UN-Habitat 2017). Local authorities in Livingstone City should prioritize the adoption of integrated urban planning frameworks that incorporate principles of sustainable development, equity, and resilience. Furthermore, in the context of Livingstone's reliance on tourism and the need to protect natural resources, integrated urban planning should prioritize strategies that promote sustainable tourism development while safeguarding the environment and empowering local communities. This aligns with several Sustainable Development Goals (SDGs), including Goal 11 (Sustainable Cities and Communities) and Goal 15 (Life on Land), which emphasize the importance of sustainable urban development and the conservation of terrestrial ecosystems (United Nations 2015). Local authorities should collaborate with stakeholders, including the tourism industry, civil society organizations, and indigenous communities, to develop tourism strategies that mitigate environmental impacts, promote cultural heritage preservation, and ensure equitable distribution of benefits. Integrating sustainable tourism principles into urban planning processes, Livingstone City can leverage its natural assets responsibly while fostering local economic development and community empowerment that contributes to a more sustainable and equitable future for all.

As discovered that Livingstone's economic transition has resulted in a geographically uneven distribution of economic activities. Certain areas have become hubs for new development, while others struggle with disinvestment and decline. Furthermore, urban street traders are exposed to hazardous environments. This spatial polarization emphasizes the challenges of ensuring equitable economic growth within the city. Improving the physical infrastructure within informal trading zones is crucial for enhancing the livelihoods and safety of street traders. Local authorities should invest in upgrading infrastructure such as drainage systems, paving passages, and public amenities in areas where informal trading activities are prevalent. This includes providing adequate shelter and facilities for informal traders. Moreover, efforts should be made to address compromised building materials used in informal trading shelters, ensuring that they meet basic safety and structural standards (World Bank 2019). By improving the physical environment of informal trading zones, local authorities can create a more conducive and dignified working environment for street traders, while also enhancing the overall urban aesthetic and functionality of the city. Exploring opportunities to integrate informal markets into the broader urban design can create a more vibrant and inclusive public realm (Geyer 2023). This could involve designating specific areas within the developments as shown in Figure 2-the Intercity Bus Terminus, shopping centres, and hotels-for formalized, well-equipped stalls for informal traders. Adopting collaboration between formal and informal sectors, and investing in infrastructure within informal trading areas, Livingstone can promote a more equitable distribution of economic benefits and reduce spatial inequalities (UN-Habitat 2016).

Livingston's economic transition has exacerbated existing housing challenges. The inadequacy of formal housing provision has fueled the proliferation of informal settlements on the city's outskirts, characterized by narrow lanes, irregular access networks, and a lack of basic services. These settlements expose dwellers to poor sanitation, environmental hazards, and inadequate living conditions. Addressing housing challenges requires a holistic approach that integrates social, economic, and environmental considerations. Investing in infrastructure within these settlements, such as drainage systems, waste management facilities, and improved access roads, can significantly improve living conditions for residents.

Furthermore, exploring opportunities for tenure security and incremental housing improvements can empower dwellers to invest in their own homes and neighborhoods. Promoting inclusive development strategies is crucial. Incentivizing the development of mixed-income housing near areas of economic activity can create a more diverse and vibrant urban fabric (Turok,2015). Moreover, exploring innovative financing mechanisms, such as microloans for home improvements, can make formal housing options more accessible to low- and middle-income dwellers (Shand 2017).

6 CONCLUSION

Livingstone's economic transition presents a fascinating case study of the interplay between economic forces and the built environment. The analysis has revealed a dynamic process of land use transformation, shifting spatial distribution of economic activities, and the need for corresponding infrastructure adaptations. These changes highlight the interconnectedness of economic development and urban form. Understanding the complexities of economic transitions and the built environment nexus qualifies to outline a course toward more resilient, inclusive, and sustainable urban futures for Livingstone City and beyond.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Infrastructure financing using Sukuks: When perception meets reality

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ABSTRACT: The relationship between infrastructure availability and economic growth has been established in literature. Despite this knowledge, Africa struggles to close its infrastructure investments gap due to non-availability of low cost sustainable financing. Sukuk financing has been touted as a sustainable alternative but uptake has been slow due to its religious-based affiliation. This study sought to assess the acceptability of sukuks for infrastructure investment in a multi-religious country such as Nigeria through a survey of procurement professionals. The results indicate support for the use of non-interest financing and the Profit & Loss sharing model of sukuks. Sukuk financing for infrastructure will relieve governments of unsustainable debt service obligations while improving In-Country value (ICV) for their citizens. It is recommended that governments in Africa create more awareness on the benefits of Sukuk financing to ensure a broad support and buy-in while investing in sukuk training for public officers.

Keywords: Infrastructure financing, Sukuk financing, Profit & Loss sharing (PLS), Africa, Nigeria

1 INTRODUCTION

Africa is growing rapidly in terms of population and with this growth comes the need for infrastructure to support the growing population. The horizon is already showing that a lot of the countries in the region may not meet the Sustainable Development Goals (SDGs) by 2030. Infrastructure is both an explicit and implicit component of the SDGs' goals and targets (World Bank 2017). Africa lags behind every other region of the world in almost all infrastructure related services that aid modern healthy living. In the energy sector, about 40% of people in the region mostly in Sub-Saharan Africa lack access and of those with access, another 40% use back-up generators (IEA 2024). In the water sector, only 39% have access to safely managed water, 27% have access to safe sanitation and hygiene (JMP 2022). In terms of road transportation, only 27.6% of Africa's over 2million kilometres of roads are paved (Biau, *et al.* 2008). A major issue facing infrastructure development in Africa as viewed by development finance institutions (DEFIs) and multilateral aid agencies is financing (Sanusi 2012; UNCTAD 2023), while Africans believe that governance and corruption should be blamed rather than

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financing (Ebekozien, *et al.* 2023). Although there is a huge amount of finance ($120 trillion) waiting to be tapped (Barwell 2023), but the owners of these resources are unwilling to commit them to infrastructure due to '*bankability*', an euphemism for profits. International project finance deals targeting Africa declined by 47% from a record $80bn in 2021 to $45bn in 2022 (UNCTAD 2023). Financing from its traditional international development partners such as the United States and the UK are also drying up as these partners are faced with crumbling infrastructure back home (USDoE 2018); (Barwell 2023). Other sources such as Eurobonds or private equity are expensive and usually accompanied by currency and interest rate risks (Sanusi 2012). Given this narrowing fiscal space, African countries need to tap new and emerging sources of financing that will not increase their already burdened debt service payments and further expose them to foreign exchange risks. One such sources is the use of Islamic Finance sukuks for financing infrastructures on the continent. Sukuks are Islamic finance equity investment instruments that give investors rights over the asset and also ensure they share in the associated gains and losses. Despite its vaunted advantages, there has been a slow uptake in Africa due to religious tensions existing between Muslims and Christians in the region especially Nigeria (Mustapha and Ehrhardt 2018). While many have argued that the inter-religious conflict is a product of desperate political actors (Iyekekpolo 2016), others believe that there are deep-seated historical rivalry between both religious (Angerbrandt 2011). These perceived conflicts are viewed as a major barrier to the general acceptance of sukuks for financing infrastructure in Nigeria. Hence, this study seeks to assess the acceptability of sukuks for financing infrastructures in Africa. Nigeria is selected for this study due to the recurring religious conflicts in the country which provides a basis for outsiders to argue that sukuks will not be accepted by the non-Muslim population within the country.

2 IMPACT OF INFRASTRUCTURE SHORTFALL

One of the key factors holding back Africa's economic development is its inadequate infrastructure system (Graff 2019). The lack of critical and basic infrastructure across Africa especially Sub-Saharan Africa (SSA) is a cause for concern with regards to meeting the SDGs by 2030. In the Transport sub-sector Africa has only 31km total paved road per 100km^2 compared to 134km in other low-income countries (Foster and Briceño-Garmendia 2010). The impact of this is that transport costs average 14% of the value of exports and even go up to 50% for landlocked countries (Biau, *et al.* 2008). The number of deaths from road accidents has risen 17% since 2010 in Africa (WHO 2023). In the water supply subsector, there is a general lack of access to clean, and safe domestic water supply. Water-borne and water-vectored diseases including lower respiratory infections (pneumonia), malaria and diarrhea are the major causes of under-five deaths in SSA. Out of the 4.9 million under-five deaths in 2022, SSA accounted for 57% (UNICEF 2024). Consequently, improving sanitation and water supply in SSA would lead to annual benefits of $10 billion and $3.2 billion respectively (Hutton 2012, p.5). In the energy subsector, 2017 figures show that only about 45% of the population has access to electricity (World Bank 2019). Even where it is available, affordability is a major issue. Poor access to energy is associated with poor health outcomes, discomfort, and poor economic, poor mental health, quality of life and intellectual development (Halkos and Aslanidis 2023).

2.1 *Current infrastructure investment approach*

The situation of Nigeria's infrastructure is depressing considering its natural resource wealth and human capital. For example, only 20 per cent of its 193,000km of roads is paved, and despite its huge oil and gas production, the power outages in the country amount to over 320 lost days a year with the population spending a whopping $13 billion annually to fuel generators (Sanusi 2012). Its health sector is in such a bad shape, its doctors are leaving the country in droves. Its academics and students are now finding solace in higher education institutions of neighbouring nations, the UK, U.S and Canada.

2.2 *Corruption in public procurement*

The Nigerian government had hitherto relied on borrowing against its resource revenue for developing infrastructure. However, poor management of the infrastructure development process (Ebekozien, *et al.* 2023), political interference (Oluseye 2024) and outright corruption have resulted in many poorly constructed and uncompleted projects. (Williams-Elegbe, 2018). Corruption has been fingered as a major issue affecting the effectiveness of infrastructure investments in Nigeria (Williams-Elegbe 2018); (Adindu 2020). While many studies conducted within the country point to corruption as the major cause of inefficient infrastructure, external multilateral bodies harp on financing as the major challenge to infrastructure development in the country (IFC 2020).

2.3 *Financing gap*

Nigeria is said to require an investment of $3 trillion in infrastructure over the next 30 years that is about $100 billion annually until 2045 to close its infrastructure gap (IFC 2020). The government has almost exhausted all avenues for infrastructure financing. And given its current debt service obligations (which is currently at 66% of revenues), it is increasingly getting more difficult to find willing lenders. Existing sources of long term financing are expensive, insist on foreign currency denominated debts due to the volatility of exchange rates in the African sub-continent. There has also been an uptick in projects with debt guarantees (World Bank 2022). Hence there is non-availability of long-term funds with risk-sharing structures (Sanusi 2012).

Another aspect of the current financing approach is the issue of cost of capital. The cost of capital for the private sector (7%-8%) is double the cost of capital for government 3%-4% (NAO 2015). It has been estimated that a one percent reduction in interest rates for the UK's over £40 billion worth of PPPs would lead to an annual saving of over £400 million (House of Commons Treasury Committee 2011). A more recent analysis found that a 1% reduction in cost of capital would lead to a reduction of $150billion in average annual financing cost for New Zealand up to 2050 (IEA 2024a). The report further found that cost of capital for infrastructure projects in developing countries is at least twice as high as that of advanced economies. These costs are often reflected in the pricing of service costs to utility users, rendering affordability a huge concern. The cost of capital represent a significant part of the cost of electricity (Hall 2016). In a 1995 analysis of the impact of interests on everyday prices found that on average cost of capital constitutes atleast 50% of prices paid by consumers (Kennedy 1995). Figure 1 below shows the cost of capital as a percentage of the price of water supply (38%), sewerage (47%) and garbage collection (12%); what this means is the that, eliminating the cost of capital can bring the prices of these services down, making them more affordable.

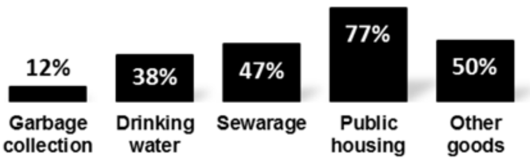

Figure 1. Amount of interest within normal prices/tariffs.

2.4 *Sukuks: An Islamic finance instrument*

Sukuks are an equity-based instrument for raising financing under Islamic financial system. *Sukuks* offers an investment solution that complies with the requirements of the Islamic faith, and is perceived as less risky due to their asset-backed nature. It is permissible to partner with non-Muslims or conventional banks as long as the venture is permissible under shari'ah (Islamic Law) and subject to Shari'ah supervision (AAOIFI 2015). Shari'ah prohibits investments in harmful ventures that are considered deleterious to society including gambling, pornography, alcohol, and speculations. The most unique aspect of this financial system is the abhorrence of interests on financing, rather it encourages and institutes a profit and loss sharing principle; a principle shared by all Abrahamic religions (Abou-Zaid and Leonce 2014). Sukuk and shares of stock are similar in two ways: they both represent ownership claims and are not guaranteed a return (Hussain, *et al.* 2015). Sukuk can either be *Asset-backed*-which involves granting the investor (Sukuk holder) a share of a tangible asset along with a corresponding share of the total risk commensurate with this ownership or *Asset-based*-which involves the issuer purchasing the underlying assets and then investing on behalf of the investors (Sukuk holders), using the funds raised through the issued Sukuk (Kammer, *et al.* 2015). The requirement to be backed by a tangible physical asset connects sukuk financing to the real economy as its returns are based on the performance of the underlying asset. Unlike the conventional debt-financed approach where the lender has to be repaid a fixed amount irrespective of the financial performance of the underlying asset. Consequently, Islamic financial products have been deployed by non-Muslim majority countries such as Germany, Luxembourg, Singapore, Hong Kong, France, Japan, China and the UK (IIFM 2016).

2.5 *Interfaith relations in Nigeria*

Generally, while there have been pockets of flared tempers between adherents of both religions (Christianity & Islam), the scale has never been as national as recent events demonstrate. For the most part, Muslims and Christians have lived peacefully alongside each other in Nigeria for a century now (Last 2007). Colonial polices towards Muslim and Christian communities institutionalized racial and religious differences with far-reaching consequences before and after independence, resulting in over 48 cases of religious upheavals between 1980-mid 2000s (Ojo and Lateju 2010). These crisis arose from the politicisation of religion in the regional contest for power with religion becoming a means for forging new coalitions (Ibrahim 1989; Iyekekpolo 2016). This polarization, and its recurrent violent confrontations, are not a product of inherent antipathies between the faiths, but of a particular mix of historical, economic, social and, in particular, political processes (Mustapha and Ehrhardt 2018). This view is supported by a recent study that found better religious tolerance in Nigeria pre-2007 and argues that, the National perception of religious intolerance is not reflected in subnational levels where greater tolerance is observed (Dowd 2016). This is why the approval of licences for the establishment of Islamic banks generated many issues and religious arguments everywhere in the country with accusation of attempts to Islamize the financial sector (Muhammad, *et al.* 2022). Majority of respondents in a study carried out in one southern state had little to no understanding about products and services of Islamic banking (Omoruyi and Idolor 2022). Despite these perceived animosity towards Islamic financial system, it is surprising that all Islamic sukuk issuances by the Nigerian government were oversubscribed on average by over 270% as shown in Table 1 below:

Table 1. FGN Sukuk Issuance 2017-2023.

Series No.	Year	Amount Sought (*Billion Naira*)	Subscription Rate	Amount Subscribed (*Billion Naira*)	Rental rate	Tenor
Sukuk I	2017	NGN100.00	105.00%	NGN105.00	16.47	7 years
Sukuk II	2018	NGN100.00	132.00%	NGN132.00	15.74	7 years
Sukuk III	2020	NGN150.00	446.00%	NGN669.00	11.2	7 years
Sukuk IV	2021	NGN250.00	346.00%	NGN865.00	13	10 years
Sukuk V	2022	NGN100.00	165.00%	NGN165.00	15.64	7 years
Sukuk VI	2023	NGN150.00	435.00%	NGN652.50	15.75	10 years
Total		**NGN850.00**	**Avg. 271%**	**NGN2,588.5**	**Avg. 14.6**	

Interestingly, the year of the Covid-19 pandemic (2020) had the highest oversubscription rate (446%) indicating a very healthy appetite for sukuks in the country contrary to the perceived investor apathy if Muslim-Christian relationships were to be a predictor of successful sukuk issuance. The success of these sukuk issuance support the claim that, at the country level, meeting infrastructure investment challenges is highly feasible and within the reach of most nations (SIWI 2005). With the decline in FDI (UNCTAD 2023) and the drying up of flows from traditional lenders who themselves now require huge investments in infrastructure renewals (Barwell 2023; NIC 2023); the Nigerian government can use sukuks to channel the increased remittance (World Bank 2023) into the country's infrastructures. The use of sukuks holds much promise if stakeholders adequately create the required awareness. Sukuks can improve service affordability, value for money (VfM) of projects along with In-country value (ICV). Even multi-lateral development agencies have begun to recognise the role that non-interest equity-based finance can play in infrastructure financing globally (IMF 2015; World Bank 2017).

3 METHODOLOGY

A literature review was carried out on infrastructure situation in Africa and Nigeria in particular. The issues covered included the role of financing, corruption and religious tensions on infrastructure investments options. Performance of current infrastructure investment models which are mainly based on multinational development banks (MDBs) designed structures were reviewed. An online questionnaire was designed to collect information on the views of a cross section of procurement professionals undertaking a World Bank-Supported procurement training short courses under the Sustainable procurement, Environmental and Social Standards Enhancements (SPESSE) pilot programme. The survey was administered on course participants many of whom are public sector procurement practitioners with public sector experience. Method of administration was a combination of stratified and convenience sampling. Employing an online questionnaire comes with the merit of being able to reach otherwise inaccessible populations (Whitehead 2007), a higher number of participants, easier to administer and respond to in this digital age (Ahern 2005) and easier to export data to analysis software while avoiding data entry errors (Jones *et al.* 2008). In total, 105 of the 108 participants responded over a two-month period, and IBM SPSS statistical software version 29 was used to analyse the data.

4 RESULTS AND DISCUSSIONS

The profile of the respondents shows that 97% of them have at least a B.Sc. while 80% have over five years' experience in procurement. Furthermore, about 49.5% of the respondents have their background in Business management and finance while 50.5 are construction professionals (*Architects, Civil Engineers and Quantity surveyors*). Seventy-five percent of the respondents work in the public sector, 13% for private sector organisation while the remainder are self-employed entrepreneurs. In terms of religious affiliation, there were 66 Muslims and 39 Christians within the sample. From the foregoing, it can be seen that the respondents possess the necessary knowledge and experience to provide credible responses to procurement related questions asked.

The respondents were asked their opinion on the current state of Nigeria's infrastructure and 52.4% classified the country's infrastructure as being in very '*poor state*' while 42.9 indicated '*fair state*' and only 4.8% indicated '*good state*'. On the most critical cause of poor infrastructure development in Nigeria, contrary to the narratives by DEFIs, 83.8% of the respondents blamed corruption while inadequate financial resources and inadequate technical expertise both earned 6.7% each and inexperienced contractors closing the rear with 2.9%. About 92.4% of the respondents also agreed that Nigerians set aside their religiosity when faced with opportunities to enrich themselves through corrupt procurement practices. This finding reinforce the contentions in some quarters that these religious upheavals are often pursued by politicians for purpose of power (Iyekekpolo 2016). Asked if they are willing to support the death penalty for anyone convicted of embezzling infrastructure funds, 76.2% answered '*Yes*', 14.3% abstained while only 9.5 answered '*No*'. Another 65% of the respondents indicated that Nigeria's electricity sector performed better under the government compared to only 19% who indicated better performance under the current private sector-led provision. Respondents were also asked which country they perceived as a better development partner to the African continent among the UK, U.S.A, France and China. Interestingly, despite all the hype to stay away from Chinese project-based lending, 74.3% of the respondents considered China a better development partner, followed by the UK (13.3%), U.S.A (9.5%) and France (2.9%).

On their willingness to invest their resources in an infrastructure development company that is led by someone they trust, 83.8% of the respondents responded in the affirmative. In terms of the most sustainable financing option for infrastructures, 51% opted for sukuk financing, 40% indicated direct government taxpayers-funding, 2.9% opted for government borrowing while 5.7% opted for Privatisations/PPPs. The low score for the privatisation/PPPs may not be unconnected with the current poor performance of the privatised electricity supply in the country. Majority of the respondents (70.5%) will support the use of sukuks for infrastructure, another 24.8 percent will support any form of interest-free financing, 1% will not support sukuks while 3.8% will only support sukuks if the word '*Islamic*' were removed. Asked to choose between two financing package for infrastructure: 10% interest bearing loan and interest-free financing where the investor is entitled to 40% of any profits made. An overwhelming 77.1% of the respondents chose the latter over the 10% interest bearing loan. This result clearly shows that the majority of respondents will not have a problems embracing sukuk financing for infrastructure once they understand how it works.

A One-Way Analysis of Variance (ANOVA) was conducted to investigate if differences exists between the respondents on several factors due to the somewhat controversial nature of the subject matter of the survey. The factors explored include respondents' geopolitical zone in Nigeria, field of study, Academic qualifications, age, employment status, years of industry experience and religious affiliations. As shown on Table 2 below, the results indicate that there were no statistically significant differences between the respondents with regards to the questions asked relating to infrastructure development and financing options.

Table 2. ANOVA results.

ANOVA	F	Sig.
GeopoliticalZone	0.87	0.504
Field of Study	1.062	0.379
Academic Qualification	0.342	0.795
Respondent age	2.336	0.102
Employment status	1.671	0.193
Years of experience	0.783	0.539
Respondents Religion	1.525	0.220

The general perception around the impossibility of financing infrastructure in Nigeria using sukuks has been based on the *perceived mutual hatred* between Christians and Muslims resulting from years of religious-tainted conflicts. However, to get a better understanding of the reality of the relationship between adherents of both religions, this study used Independent samples T-test to analyses the responses to three *sukuk-related questions* and the results are shown on Table 3 below. The results shows that there were no statistically significant differences between adherents of both religions in terms of sukuks being a more sustainable financing option (sig. 0.132) and Islamic profit-sharing principle (sig. 0.320) being preferred over fixed return interest-based investing. However statistically significant differences emerged on the question of support for sukuks (sig. 0.004).

Table 3. Independent samples T-test -Muslims vs Christians on sukuks.

Independent Samples T-test	F	Sig.
Most Sustainable financing	1.026	0.132
Support for Sukuks	17.457	0.004
Loan (Profit-Sharing) Conditions	3.72	0.320

To unravel the cause of the difference, a cross tabulation of responses to this particular question by adherents of both religions was performed and the results converted to a bar chart as shown in Figure 2 below. It can be seen that 51% (20 respondents) of the Christian respondents support deploying sukuks for infrastructure financing while about 39% (15 respondents) will support *any interest-free* financing. This result indicates that the respondents acknowledge the sustainability of interest-free financing whether it is Islamic finance or otherwise. However, just under 8% (3 respondents) of the Christian respondents indicated their support conditional upon the removal of the word 'Islamic' from the sukuks while 2.56% (1 respondent) would not support the use of sukuks. Overall, it is clear that interest-bearing financing has been understood by most respondents as being an unsustainable form of financing infrastructure in Nigeria.

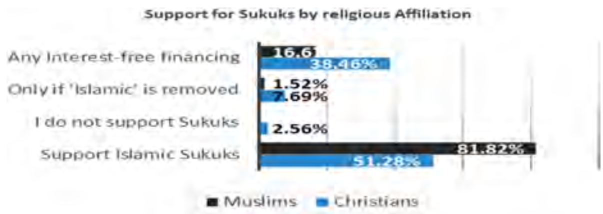

Figure 2. Support for Sukuks by religious affiliation.

From the foregoing, it is clear that the general perception regarding the problems of infrastructure development in Africa is being misdiagnosed by the various DEFIs. This has led to treating the problem with the wrong medicine: *more debts*. This is why it is no surprise that World Bank projects in Africa have a success rate of only around 50% (Ika, *et al.* 2012). The results of this study also shows that corruption rather than financing was a major problem that has reduced the efficiency of infrastructure investments in the region. Now that *perception has met reality*, it is clear that majority of Christian procurement professionals (*at least 51.28% of those who participated in the survey*) are not opposed to the use of sukuks for the financing of infrastructure. Governments in Africa should create awareness programmes to provide a better understanding of sukuks for their citizens in order to engender better acceptability.

5 CONCLUSIONS

This study set out to assess the perception of the acceptability of using sukuks for financing infrastructure in Nigeria given the perceived animosity between Muslims and non-Muslims in the country. From the results of the study, with data collected from a diverse cross section of procurement professionals, it is clear that every Nigerian just wants good infrastructure and are less concerned about what the financing instrument is called. The increasing deaths on Nigerian roads and hospitals, declining academic quality and poor electricity services affect everyone irrespective of religious affiliation. The government should urgently devise a means to channel the huge remittance volumes flowing to the country into infrastructure. The proposed Diaspora bond can be re-christened into Diaspora sukuk, since bonds denote debts while sukuks denote equity, thereby relieving the government of additional debt service obligations.

5.1 *Practical implications*

Between 2019 and 2021, 25 African countries spent more on interest payments than on Health investments while 7 countries spent more on interests than on Education. Nigeria, along with many other African countries are struggling with debt repayment issues and the conventional advise from Multi-Lateral development agencies-*borrow to grow*-is no longer an option given increased borrowing costs. Despite these fiscal conditions, infrastructure investments is imperative for Africa. The use of equity-based financing such as Sukuks hold a lot of promise since they do not require any fixed debt repayment regimes. Furthermore, sukuk-based financing based on local currencies will help avoid foreign exchange risks associated with Africa's current debts which are predominantly based on foreign currencies. Nigeria's current debt stands at 39.8% of its GDP while spending over 66.9% of its revenue for debt repayment.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

The role of infrastructure in financial inclusion – An integrative review

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ABSTRACT: Financial inclusion is critical as it empowers individuals, fosters economic stability, and promotes inclusive growth by granting all access to essential financial services. The progress and efforts toward digital financial inclusion should synchronise and contribute to achieving the 2030 Sustainable Development Goals. Infrastructure facilitate access to financial services and serves as a catalyst to expand financial services, reaching underserved communities, however many developing countries lack the infrastructure required. The study aims to understand how components of infrastructure, such as physical and technological, influence the accessibility, availability, and effectiveness of financial services. The paper integratively reviews existing studies in Scopus on the role of infrastructure in financial inclusion. The synthesis highlighted the infrastructure required, the significance of connectivity between technologies and strategic coordination in infrastructure provision to enhance financial inclusion, thus enabling sustainable economic development. The findings will be beneficial to policymakers in developing countries in devising effective strategies to expand access to financial services.

Keywords: financial inclusion, infrastructure, financial services accessibility, sustainable economic development, developing countries

1 INTRODUCTION

1.1 *Background*

Financial inclusion is a critical enabler of sustainable economic development, enhancing the 2030 Sustainable Development Goals (SDGs). Sustainable development is a shared goal worldwide, where financial inclusion and infrastructure are vital for sustainable development. Financial inclusion aims for sustainable, equitable development, ensuring its benefits reach everyone (Arner *et al.* 2020). It is the universal access to financial services and products offering numerous advantages. It aids in the effective distribution of productive resources, enhances the management of daily finances and provides secure savings options (Sarma and Pais 2011).

Furthermore, it diminishes the proliferation of informal, exploitative credit sources. Subsequently, it promotes efficiency and welfare (Sarma and Pais 2011). While significant strides have been made globally to promote financial inclusion, and policymakers have prioritised financial inclusion (Sarma and Pais 2011; Global Partnership for Financial Inclusion (GPFI) 2016; World Bank 2018), challenges persist, particularly in ensuring access to underserved populations related to financial exclusion. Financial exclusion is when specific social groups (often the poor or underprivileged) are excluded from the formal financial system (Conroy 2005; Leyshon and Thrift 1995). Even developed countries with comprehensive financial systems struggled with complete inclusivity, which generally affected individuals with limited income or a track record of poor debt management (Kempson and Atkinson 2004).

In recent years, the role of infrastructure has garnered increasing attention in shaping the landscape of financial inclusion. Infrastructure is essential for accessing financial services,

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enabling more effortless mobility and raising awareness about available financial services (Sarma and Pais 2011). The determinants of financial inclusion are numerous, and their interplay is intricate. Rather than delving into how multiple factors collectively influence financial inclusion, this paper focuses on infrastructure's role. Ths study argues that better infrastructure facilitates financial inclusion.

The research follows a literature review of existing research to explore how infrastructure development and improvements can enhance the reach and effectiveness of financial services, especially in marginalised communities. Through a comprehensive analysis, this article aims to elucidate the pivotal role of infrastructure in advancing financial inclusion efforts worldwide.

2 LITERATURE REVIEW

2.1 *Financial inclusion*

Financial inclusion offers affordable costs to all communities, rich, poor, low-income or with historically bad debt. Efficient financial management through financial inclusion reduces poverty and supports economic growth (Arner 2020; Sharma 2016). Research suggests a positive correlation exists between economic growth in developing countries and different aspects of financial inclusion, notably banking services' penetration, availability, and usage, particularly in deposits (Sharma 2016). It diminishes individuals' susceptibility, facilitates savings, enhances daily efficiency, shares and spreads financial risks, and promotes economic expansion (small and medium businesses).

The Global Findex Database 2021 indicated that 24 per cent of adults worldwide are unbanked (no account at a bank, financial institution or mobile money) (Demirgüç-Kunt *et al.* 2022). Developing countries are disproportionately affected by financial exclusion, with millions lacking access to basic financial services. Although account ownership has increased by eight percentage points to 71 per cent in 2021, it is still lower than the 76 per cent worldwide (Demirgüç-Kunt *et al.* 2022). Notable advancements in account ownership and usage have been noted for developing countries, with an eight percentage point increase in 2021 from 2017; however, if unforeseen expenses arise, about 50 per cent of adults can not access additional funds within 30 days and approximately two-thirds of adults expressed concerns about at least one aspect of financial stress in developing countries (Demirgüç-Kunt *et al.* 2022).

The drive for financial inclusion is to expand financial services for adults with accounts and increase account ownership for unbanked adults. Unbanked adults cited two main reasons they do not have a bank account: insufficient documentation and the distance to the closest financial institution (Demirgüç-Kunt *et al.* 2022), which allude to the opportunities through infrastructure to address these main obstacles.

2.2 *Infrastructure*

Infrastructure encompasses various components supporting financial inclusion, from physical to digital elements. It typically denotes extensive physical systems like transportation networks, sewage systems, and electrical grids. However, it also encompasses various elements, such as information and communication banking infrastructure, and plays a multifaceted role in facilitating access to financial services and fostering economic participation. Another approach is to focus less on specific systems and more on how socio-technical systems facilitate fundamental, often overlooked functions constructed from a combination of old and new devices (Bernards and Campbell-Verduyn 2019). In this context, infrastructures serve as both a conceptual tool and a collection of objects, emphasising five fundamental traits: facilitation, openness, durability, centrality and obscurity (Bernards and Campbell-Verduyn 2019).

Subsequently, in global finance and financial inclusion, infrastructures involve modern and traditional systems that facilitate payment processing, pricing, and risk evaluation. These infrastructures comprise a mix of physical and digital components like roads, transportation networks, fibre-optic cables, computers, servers, mobile and payment cards, and a multitude of human practices such as software development, statistical modelling, and algorithmic automation (Bernard and Campbell-Verduyn 2019). As dynamic socio-technical systems, infrastructures blend human and non-human elements to support essential functions within the globe. Considering all the many components of infrastructure, there are evident opportunities to mitigate the obstacles experienced by the unbanked to improve financial inclusion.

3 METHOD

An integrative review was conducted. This approach to literature review can be used to identify central issues in an area, bridging the gaps between related works (Russell 2005). The process suggested by Whittemore and Knafl (2005) was followed, including specifying the review purpose, searching the literature, evaluating data from various sources, analysing data, and presenting the findings. The literature search was performed using the Scopus database. The keywords included “financial inclusion” AND “infrastructure”. The search delivered 304 search results, and when limited to articles, there were 221 articles. An interesting observation is the growth in publications in recent years. Of the 221 articles, the majority were published in the last ten years, whereas only 13 were published in 2014 or before. The first relevant publication from the search results was published in 2011 and has the most citations (Sarma and Pais 2011). The researcher worked through the articles to identify studies reporting specifically on the role of infrastructure in financial inclusion.

Thematic analysis was used to analyse information from the materials identified. A three-step approach to thematic data analysis in integrative review was used, as supported by Dhollande *et al.* (2021). These included coding, organising the codes into themes and amalgamating the descriptive themes into analytical themes. This enabled the identification of themes and patterns emerging from the literature. The themes are presented and discussed in the next section.

4 FINDINGS

4.1 *Digital financial inclusion*

Digital financial inclusion has emerged as a new concept and garnered significant attention in various studies (Aziz and Naima 2021; Mushtaq and Bruneau 2019; Niu *et al.* 2022). Digital financial inclusion entails providing access to financial services through technological means, including the internet, mobile networks, cards, digital wallets, and similar platforms. It aims to integrate underserved and financially marginalised populations into the formal banking system. Digital financial inclusion or digital inclusive finance was included in the title or abstract of 27 search results on Scopus, although not all were relevant to this literature review. The first study that included digital financial inclusion was in 2018, highlighting that it is a relatively new concept related to infrastructure. However, it has exponentially grown in the last three years. The significance of infrastructure in promoting digital financial inclusion is discussed within the appropriate infrastructure sections to emphasise infrastructure rather than the specific type of financial inclusion.

4.2 *Developing and least developed countries*

The majority of the studies included in the review are from developing countries, emphasising the focus on the infrastructure required for financial inclusion where it is needed most. Infrastructural development has been identified as one of the factors that significantly affect financial inclusion in developing countries and least-developed countries, including India (Yadav and Sharma 2016), Bangladesh (Siddik *et al.* 2015), Indonesia (Ali *et al.* 2020) where infrastructure is the third most impactful factor affecting Islamic financial inclusion, and in Rwanda infrastructure was the most significant factor for street vendors (Irankunda and Van Bergeijk 2020).

4.3 *Physical infrastructure*

Sarma and Pais (2011) found that physical infrastructure for connectivity is crucial and significantly positive in improving financial inclusion. They found that newspapers, cable TV, computers, and radio do not have the same significant relationship as internet usage and telephone usage, which shows a positive correlation with the extent of financial inclusion. Sarma and Pais (2011) findings suggest that connectivity and access to information are critical factors in fostering financial inclusion. The interplay between physical infrastructure and financial inclusion underscores the significance of strategic development initiatives to bolster infrastructure to ensure equitable access to financial services and stimulate overall socio-economic progress.

Dangui and Jia (2023) examined the impact of financial inclusion on bridging the financing gap for water infrastructure in Togo, a developing country. Through various robust estimation techniques, it was discovered that financial inclusion correlates with increased access to improved drinking water and reduced travel time to water sources, particularly in poor rural areas, households headed by females, and the country's northern region. The research underscores the importance of physical infrastructure for accessing drinking water, which substantially influences formal inclusive finance more than informal financial inclusiveness, which lacks a considerable impact.

Pradhan and Sharma (2022) examined the diversity in financial inclusion and its factors across Indian states classified by income brackets and geographic regions. Per capita power consumption, the extent of national highways, and the length of railway routes play a positively significant role (in addition to other factors) in shaping financial inclusion for 2018-2019. This could be attributed to the political administration's focus on infrastructure and energy sector advancement, which highlights the role of physical infrastructure.

Suhrab *et al.* (2024) found that digital financial inclusion has a notable adverse impact on income inequality in the context of BRICS countries, with technology innovation and physical infrastructure development amplifying this effect. The research underscores the significant role of infrastructure development in decreasing income inequality. As infrastructure advances, it enhances access to financial services and markets, fostering financial inclusion and diminishing income inequality.

Infrastructure distribution often exhibits disparities, particularly between urban and rural areas, with the latter usually facing inadequate infrastructure compared to urban centres (Suhrab *et al.* 2024). This imbalance can exacerbate the gap between urban and rural communities, where rural areas may lack sufficient transportation networks, safe water sources, and reliable electricity, limiting economic opportunities and hindering social mobility. Pandey *et al.* (2022) argue that deficient infrastructure in rural regions can trap individuals in poverty and impede their ability to thrive. Several of the studies highlighting the role of infrastructure on financial inclusion focus on communities in rural areas (Joshi 2012; Ngo 2019; Niu *et al* 2022; Siddiqui and Siddiqui 2020) where digital financial infrastructure plays a significant role in access to financial services. This is also seen from the interplay between digital and physical infrastructure required to enhance financial inclusion.

Physical infrastructure is pivotal in fostering financial inclusion by enhancing accessibility to financial services. Accessible roads, such as a network of paved roads, reliable transportation, and communication networks, facilitate the establishment of banking facilities in remote areas, enabling underserved populations to access banking services.

4.4 *Digital financial infrastructure*

Digital infrastructure refers to the infrastructure required for digital finance, digital financial services or fintech. Digital finance is the influence of emerging technologies on the financial services sector to provide real-time payment services, mobile money, and identity authentication, among others. Their scalability enables their application to hundreds of millions of customers, even for low-value transactions (D'Silva *et al.* 2019).

D'Silva *et al.* (2019) observed that conducting low-cost, high-volume, low-value digital financial transactions a decade ago seemed unimaginable. Numerous studies have underscored the benefits of digital inclusive finance, bypassing the need for costly and time-intensive financial infrastructure construction. This significantly lowers the operational expenses for financial institutions, enhancing the penetration rate of financial services. Consequently, there is a notable improvement in the accessibility of financial resources, particularly for marginalised groups excluded by conventional financial institutions. Studies used different terminology for referencing the required infrastructure, ranging from digital, technology, and information and communication infrastructure.

Kouladoum *et al.* (2022) examined the relationship between digital technology and financial inclusion across 43 Sub-Saharan African nations. Digital technology (subscription rates of fixed and mobile telephones, fixed broadband, internet usage, and a combined measure of digitalisation as information and communication technology indicators), consistently exhibits positive and significant impacts on financial inclusion at various levels. Aduba (2021) and Ngo (2019) found similar results, where safe digital financial services are necessary for a sustainable cashless economy and financial inclusion in Nigeria (Aduba 2021), and in Asia economies, infrastructure supporting mobile phone subscriptions directly influences financial inclusion (Ngo 2019). A mega-infrastructure project 'Aadaar' was developed in India in 2010 for biometric-based identification of 1.2 billion residents, and it survived despite strong opposition. Srinivasan and Johri (2013) argued that it's survival was due to its promise and contribution to financial inclusion and poverty reduction.

Numerous nations have initiated efforts to establish the fundamental conditions for digital financial services to achieve sustainable scalability; however, it necessitates a more comprehensive array of supportive elements to guarantee financial integrity, stability, and competitiveness (Pazarbasioglu *et al.* 2020). Some developing countries require the necessary digital infrastructure; however, it is not always used optimally. In India, a study examining the low adoption of digital payment technologies for small businesses found that infrastructure is not the reason for low adoption as these businesses have the necessary infrastructure with smartphones and banking accounts (Ligon *et al.* 2019). However, in Pacific Small Island Developing States (SIDS), Hahm *et al.* (2021) observed a lack of basic digital infrastructure, and in regions with a more advanced technological infrastructure, fintech services have gained significant traction. Bhatnagar and Grima (2023) investigated the potential synergy between entrepreneurship and digital initiatives in enhancing financial accessibility within India. The findings highlight a robust correlation between the expansion of digital infrastructure and increased financial inclusion. Entrepreneurs have capitalised on this infrastructure to provide innovative services to previously unbanked individuals. The study emphasises the ongoing need for initiatives to enhance infrastructure and foster widespread financial inclusion.

Jimenez *et al.* (2023) examined the correlation between Mexico's economic growth and financial inclusion. They noted that digital devices have emerged as a notably significant factor in fostering both financial inclusion and economic growth. Arner *et al.* (2020) focused on promoting financial technology to ensure financial inclusion. They argued that four pillars of digital financial infrastructure are required for economies to see a digital financial transformation, where pillars two and four include the infrastructure needed. Arner (2020) concluded that the foundation of a digital financial infrastructure strategy relies primarily on the presence of communication infrastructure.

4.4.1 *Real-time retail payments*

Buckley and Balakrishnan (2020) emphasised the importance of national infrastructure to support real-time retail payments systems (RTRPS), predicting the growth of more than 100 more countries to join the existing 54 countries in 2020. They found that real-time retail payments have become a critical service in developed countries and might take longer for developing countries. The infrastructure to drive more use of digital payments often relies on complementary developments, such as the widespread adoption of smartphones and QR-code-based payment methods. Buckley and Balakrishnan (2020) found that any decrease in the dependability of the real-time retail payment infrastructure would significantly affect the economy's operation. The researchers suggested that jurisdictions intending to introduce retail real-time payments should consider that such a system will inevitably evolve into critical infrastructure, with its reliability becoming crucial for the economy's smooth operation.

4.4.2 *Internet or broadband infrastructure*

Elouaourti and Ibourk (2024) investigated the determinants of access to and utilisation of digital financial services in African nations. One of the key factors pivotal in fostering digital financial inclusion is the availability of technology and internet infrastructure.

Niu *et al.* (2022) investigated the correlation between the extensive deployment of broadband infrastructure and digital financial inclusion in rural areas of China. The findings indicate a substantial contribution of broadband infrastructure to digital financial inclusion, where the researchers differentiate between two aspects of digital inclusion: coverage and usage. While broadband infrastructure enhances coverage, its impact on usage is constrained. Moreover, the influence of broadband infrastructure on the usage aspect of digital financial inclusion is more pronounced in regions with elevated levels of human and social capital and greater penetration of bank branches. Considering these moderating factors is crucial for maximising the effectiveness of broadband infrastructure in promoting financial inclusion (Niu *et al.* 2022).

Aziz and Naima (2021) found that regular access to the internet remains a notable obstacle to achieving basic connectivity in advancing financial inclusion. Although online banking services are available, lack of internet or interrupted internet in rural areas, among others, restrict digital financial services. These communities often include poor and low-income households.

4.4.3 *Information and communication infrastructure*

Information and communication technology also called ICT and which includes telecommunication, was a recurring concept identified in the search results (Agyekum *et al.* 2022; Kouladoum *et al.* 2022; Mushraq and Bruneau 2019; Pradhan *et al.* 2021). Communication infrastructure is crucial in enhancing financial inclusion enabling widespread access to financial services, especially for people experiencing poverty and the unbanked (Mushtaq and Bruneau 2019). Its role in facilitating digital transactions and information dissemination expands financial access to underserved populations. Many studies have highlighted the lack of basic digital finance and resources crucial for financial inclusion. Physical infrastructure is often a challenge in rural or remote areas where communities do not have access to financial services, resulting in a focus on digital financial services through the internet and mobile, enabling unbanked communities to be connected to the formal financial system. The availability of wireless telecommunication facilities has unlocked substantial market opportunities that commercial banks can tap into to expand their services and products into rural areas where banking services are limited (Joshi 2012). By leveraging information and communication technology and infrastructure, banks can create innovative banking models to reach previously underserved populations (Joshi 2012).

Mushtaq and Bruneau (2019) examined the factors influencing financial inclusion, especially in developing nations, with a positive correlation between information and communication technologies and financial inclusion, alongside a negative link with poverty and inequality. Additionally, the study suggests that financial inclusion, regardless of measurement, contributes to poverty alleviation. The study recommends policymakers focus on information and communication infrastructure to advance financial inclusion.

In Brazil, the government introduced a boat servicing as a travelling bank branch through information and communication technology to address the financial requirements of the riverine populace residing in an extensive area characterised by a sparse population, challenging transportation access, and limited availability of ICT infrastructure. Joia and dos Santos (2019) evaluated the influence of this mobile banking initiative (information and communication infrastructure) on the financial inclusion of the area's inhabitants. The initiative succeeded in offering access to financial offerings; however, insufficient financial literacy and context-specific concerns regarding information and communication technology infrastructure have impeded financial inclusion.

Information and communication technologies improved financial inclusion in South-East Asia to access credit facilities for small businesses (Agyekum *et al.* 2022), and in India which improved telecom accessibility enhances awareness, capability, and utilisation of banking services (Siddiqui and Siddique 2020), highlighting the focus on enhancing technological infrastructure.

In Ghana, Liu *et al.* (2023) found that incorporating information and communication technology and embracing mobile banking/money adoption positively affects financial inclusion, among others.

4.4.4 *Mobile money*

Several studies have reported on mobile money (Aron 2018; Ligon *et al.* 2019; Peruta 2018; Reaves *et al.* 2015), a relatively new concept transforming financial inclusion, especially in developing countries. Between 2017 and 2021, there was an 8-percentage-point rise in account ownership across developing economies, climbing from 63 percent to 71 percent among adults. In Sub-Saharan Africa, much of this growth is attributed to the uptake of mobile money (Demirgüç-Kunt *et al.* 2022). Mobile money entails a mobile-centric service offering affordable financial services to individuals marginalised from traditional banking channels (Della Peruta 2018). Mobile money addressed challenges from inadequate institutional infrastructure and traditional banking systems' cost. Through the adoption of mobile money, where traditional banking systems have underserved individuals, they have obtained a secure method for transferring and making payments at a reduced cost. In Sub-Saharan Africa, 33% of adults possess a mobile money account, surpassing the global average of mobile money account ownership at 10 per cent. This figure represents the highest percentage among all regions worldwide (Demirgüç-Kunt *et al.* 2022). Unfortunately, mobile money does not always offer the same protection as the formal banking system. Reaves *et al.* (2015) found that most of these applications lack the safeguards required for financial services, and the customers (those who can least afford them) bear an unfair liability burden for these issues. This risks trust in branchless banking and impedes efforts toward global financial inclusion.

4.5 *Future studies*

While the focus of this paper relates to the infrastructure required for financial inclusion, studies also observed that financial inclusion is pivotal in fostering the development of a robust and effective financial infrastructure (Sharma 2016) and the relationship between financial inclusion and infrastructure (Daud and Ahmad 2023). Furthermore, there are different views, one of which assumes a positive causality from infrastructure to financial inclusion and the other from financial inclusion to infrastructure (Pradhan *et al.* 2021). This highlights the intricate role each plays in the other. Future studies could consider these relationships in research.

5 CONCLUSION

This literature review sheds light on infrastructure's role in fostering financial inclusion. Adequate infrastructure extends financial services to marginalised communities, facilitates easier transactions, encourages entrepreneurial activities, and promotes economic growth. Infrastructure is the backbone of financial inclusion efforts, providing the necessary framework for individuals to effectively access and utilise financial services. While there is a wealth of research on financial, digital, and information and communication technology infrastructure, studies focusing on physical infrastructure are limited. This may signal a shift in the increasing importance of digitisation. As societies evolve and where there is already traditional physical infrastructure, such as roads and buildings, the focus may increase on digital infrastructure like internet connectivity and mobile networks. This transition reflects broader trends towards digitalisation, where technological advancements play a central role in facilitating access to essential services, including financial inclusion. Understanding these dynamics is crucial for policymakers and stakeholders to effectively allocate resources and address the evolving needs of communities in an increasingly digital world.

The findings from the review suggest that digital infrastructure has emerged as a crucial driver of financial inclusion; however, challenges persist, particularly in regions with inadequate connectivity. The world has progressively moved towards digitisation and communities should not be left behind. Access to infrastructure is critical to access financial services. Governments and policymakers should therefore aim to address some of the challenges identified in this study including costly and time-intensive infrastructure delivery. Addressing these challenges will ensure that all segments of society have access to the infrastructure necessary for financial inclusion, thereby fostering economic growth and social development. Market participants can also work with the government to provide infrastructure and financial services at low cost, and close the gaps and challenges in institutional infrastructure. Supporting financial institutions to provide digital services at subsidised rates could contribute to financial access and inclusion.

The study's major limitation lies in the review approach used, which could have resulted in omitting relevant documents from the study. More studies could employ other research techniques to examine the relations between infrastructure provision and financial inclusion.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Urban transport infrastructure financial investments pooling in Southern Africa: A bibliometric analysis

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ABSTRACT: Urban Transport Infrastructure in Southern Africa is multifaceted but faces major challenges. In the past decades, various efforts have aimed at enhancing urban public transport investments across all government levels. What remains to be documented convincingly though, is complexity of coordinating diverse stakeholders, managing regulatory inconsistencies, and securing sufficient financial resources for infrastructure transportation projects. This study adopts a bibliometric analysis to provide a comprehensive investigation of the challenges, dynamics, and potential strategies concomitant with pooling public transport financial investments in Southern Africa. VOSviewer and Biblioshiny are employed for the analysis. The key study findings propose a framework to facilitate sustainable transport infrastructure. By syncing the current practices, the study contributes insights to create a comprehensive financing model to ensure a sustainable and smart mobility infrastructure pool in Southern Africa.

Keywords: Urban Transport Infrastructure, Financial investment, Bibliometric analysis, Financial model

1 INTRODUCTION

Accessibility and efficient transportation infrastructure are the lifeblood of thriving cities globally (Domingo *et al.* 2024). This capable transport infrastructure permits people to connect with their daily essential amenities and services such as healthcare centres, jobs, educational institutions, and commercial and business zones. Moreover, such a transportation infrastructure also enhances the quality of life (Sobnath *et al.* 2020). However, on a global scale, many urban spaces meet with significant challenges within their urban transport infrastructure. These challenges include limited funding and traditional financing mechanisms such as public-private partnerships (PPPs) and government budgets habitually struggle to meet the ever-expanding demand for public infrastructure investment. Unequal access as a challenge is also associated with vulnerable populations, marginalized communities, and informal settlements. This particularly applies to low-income communities which are disproportionately affected by unaffordable and inadequate transportation options. Lastly, Singh (2012) indicates that many cities lack sufficient public transport networks and safety measures, leading to congestion, lack of reliable maintenance, and accessibility issues.

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Urban transport infrastructure consists of a diverse range of components that form the backbone of a well-functioning urban environment. These components include public transport systems, roads and bridges, and other critical elements such as transit-oriented development. The challenges facing Southern African nations are developing urban infrastructure that will meet the demands of the present and foster sustainability for future generations (Omisore 2018). Additionally, financial investment denotes the lifeblood of infrastructure development leading to the provision of capital for planning, construction, and maintenance. The pooling of financial resources is therefore emerging as a prominent approach that is fostering a collaborative framework for focusing on complex funding requirements associated with mega projects for urban transport infrastructure (Tozer *et al.* 2023). Considering these issues, this paper offers a potential solution aligned with financial pooling mechanisms. Additionally, the paper reveals that pooling diverse public and private sources presents the opportunity to unlock larger-scale investment, enhance project selection, and diversity risk mitigation.

2 RESEARCH METHOD

Bibliometric analysis reveals the influence of the research landscape within a specific focus of research (Li *et al.* 2023; Postelnicu and Boboc 2024; Xu *et al.* 2024). Its primary significance stems from its ability to quantitatively analyse large volumes of data and identify patterns, trends, and research activities, and trace research origins (Gan *et al.* 2022). Bibliometric analysis was adopted in this study to comprehensively analyse urban transport infrastructure within the financial investment landscape. Web of Science (WoS) and Scopus were the two databases selected for conducting the comprehensive analysis of the urban transport and financial investment literature review. Often in bibliometric analysis, WoS is utilized as the primary database due to its ability to offer comprehensive coverage of high-quality and robust assessment of the scientific research landscape (AlRyalat *et al.* 2019; Yadav and Banerji 2023). However, Scopus was also used to provide interdisciplinary coverage within the literature (Mongeon and Paul-Hus 2016). The search was performed using the following keywords: "Urban transport infrastructure" AND "Investment" across all fields of disciplines.

This study adopted the systematic approach to conduct bibliometric analysis by utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). PRISMA allows for a transparent and rigorous data collection and analysis process (McGowan *et al.* 2020; Page *et al.* 2021).

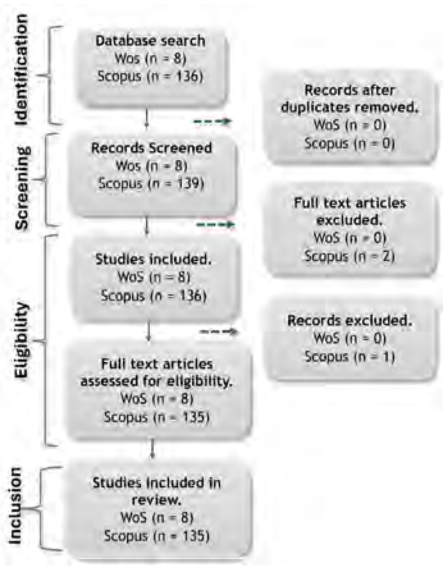

Figure 1. Overview of the methodology applied to bibliometric analysis [Source: Authors, 2024].

This includes the search strategy, data extraction approach, and quality assessment procedure. The initial output identified 8 publications in WoS and 139 in Scopus (Figure 1) for further screening. In total, 147 full-text articles were assessed and included for full-text review and analysis (Figure 1). Data analysis was carried out using Biblioshiny (R Studio) and VOSviewer software. Overall, the employment of bibliometric analysis in this study comprehensively revealed the core state of research in urban transport infrastructure and the status of financial investment in Southern African countries.

3 FINDINGS

3.1 *Key themes and emerging trends*

The co-occurrence analysis was carried out globally, and the results yielded five clusters presented by different colour codes (Green, Blue, Red, Purple, and Peach). In the green cluster, the keywords are investment, urban transportation, transport systems, and economics. The emerging themes globally are related to urban transport, urban transportation, transport infrastructure, investment sustainable development, and transport infrastructure among others (Figure 2). However, other 'peripheral' issues are related to accident prevention, urban renewal, traffic congestion, sustainable mobility, and public-private partnerships. This reflects the interdisciplinary nature of the study area and the breadth of the research that feeds into urban transport infrastructure financing. Interestingly China stood out among the 'global themes' on urban transport infrastructure financing, signifying its growing influence through its Belt and Road Initiative ahead of other funding windows in Southern Africa such as the World Bank and African Development Bank (Anguelov 2021).

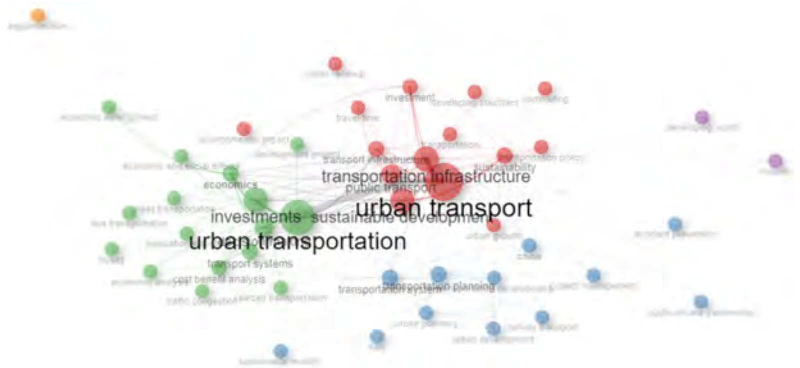

Figure 2. Co-occurrence network on global analysis [Source: Authors, 2024].

There is an ambiguous relationship between investment and transportation infrastructure. For instance, a study conducted by Bono *et al.* (2022) determined the relationship between international attractiveness and investment in the public transport infrastructure. Strong evidence was found that the attractiveness of cities that have attracted tourism was based on their investment in public transport infrastructure. Public-private partnerships (PPP) have also influenced successful investments in improving transport infrastructure (Bae and Joo 2016). The developing world and mobility are the only emerging themes in the purple cluster. However, if investments in transport infrastructure are not balanced, this may have a short negative impact on social services such as education therefore requiring a balance of priorities within the socio-economic and environmental aspects (Muvawala *et al.* 2021). Lastly, agglomeration is the only keyword in a peach-coloured cluster. Improvements in transport infrastructure therefore impact spatial relationships, potentially leading to agglomeration effects (Bothe *et al.* 2018).

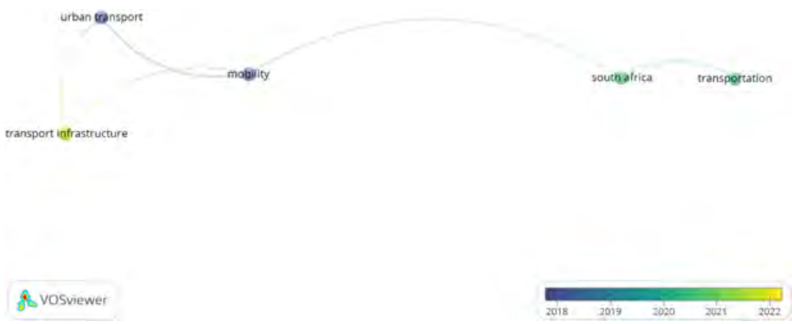

Figure 3. Co-occurrence network on Southern African analysis [Source: Authors, 2024].

On the other hand, in Southern Africa, the keywords analysis yielded three clusters presented in blue, yellow, and green colour coding (Figure 3). Notably, not much has been researched within the focus area of this study, and most of the research between 2018 and 2020 was on urban transport and mobility presented by a blue cluster. From 2020 to 2021, researchers were more focused on issues around transportation in South Africa. For instance, Musonda *et al.* (2019) examined the organizational structures of the Addis Ababa City Light Rail Transit (AA-LRT) system in Ethiopia and the Gautrain railway in South Africa. Findings reveal that the political and social context has an impact on the structure of these projects. Moreover, it is essential for conducting thorough feasibility studies and providing crucial evidence for transport infrastructure stakeholders to make informed decisions (Okoro *et al.* 2021).

3.2 *Key authors countries in urban transport infrastructure research in Southern Africa*

Figure 4 shows the countries of key authors within the urban transport infrastructure financial investment domain.

Figure 4. Authors countries [Source: Authors, 2024].

The chart shows some countries that produced the most scientific documents based on multiple country publications (MCP), such as China, the Netherlands, Australia, and the United Kingdom.

For single-country production (SCP) in this study, it was China and Australia. The research topic of financial investment in urban transport infrastructure has been primarily influenced by these countries. Most authors' publications on Southern Africa are from countries in the global North, and the realities in Southern Africa are frequently overlooked in these publications. South Africa is the sole country represented in this region, suggesting that there is even less literature published in this area.

3.3 *Financing mechanisms for the urban infrastructure*

Financing infrastructure is based on evidence that infrastructure development pathways have significant impacts on the economy. For instance, the colonial infrastructure in Southern Africa and Apartheid South Africa still marks the landscapes of Southern African cities (Cirolia *et al.* 2021). Moreover, infrastructure in Southern Africa is financed by multilateral development banks such as the World Bank, the New Development Bank (based in Shanghai), the European Investment Bank, the Asian Development Bank, and the Africa Development Bank (Cirolia *et al.* 2021). In South Africa, the Gautrain Rapid Rail System connecting Johannesburg, Pretoria, and Ekurhuleni was funded by a PPP model that included government grants and private-sector equity (Musonda *et al.* 2019). This rapid rail transit system reduced road transport congestion, rejuvenated central Johannesburg, and promoted rail transport in Gauteng Province. In Botswana and Zambia, the completion of the Kazungula Bridge was funded by the Governments of Botswana and Zambia, the African Development Bank, the Japanese International Cooperation Agency, and the Euro- pean Union (AfDB 2011). This resulted in increased traffic flows, trade, and competitiveness as well as the growth of the surrounding towns of Kasane, and Livingstone (AfDB 2011). In the context of Lesotho, funding for transport infrastructure is a multidimensional effort, with the World Bank playing a critical role in financing and enabling development in Lesotho of transport infrastructure projects (The World Bank 2023). These projects were selected to highlight the financing mechanisms and improvements therefore that result from financing road infrastructure projects.

Besides the World Bank, AfDB, and UE, China, Japan, and India have expanded infrastructure investments in African national revitalization plans to boost domestic industry and promote trade (Jiang 2019). These infrastructure investment initiatives have been tied to commercial financing, and the respective Chinese and Japanese governments' involvement in building physical infra- structure (Jiang 2019). In addition to the trade promotion initiatives, some funding mechanisms for infrastructure investment have been tied to natural resource-based infrastructure loans (Cirolia *et al.* 2021). A notable example is China's investments in Angola which are designed to give China preferential access to Angola's oil industry (Cirolia *et al.* 2021). In this funding mechanism, the natural resources are used for repayment or as collateral for infrastructure loans. While China is the largest actor, there are many players in resource-based lending for infrastructure development, and the resources used as collateral include minerals, cocoa, tobacco, and sesame seeds (Bautigam 2011).

3.4 *Growing demand for transport infrastructure and the need for investment*

Infrastructure development financing to achieve economic growth is at the top of the development agenda for many countries (Anguelov 2021). For instance, studies in Nigeria found that investment transportation infrastructure had a positive impact on the GDP growth (Babatunde 2018; Ibrahim *et al.* 2022). A similar study found that investment in road, transport, and housing positively affected the GDP growth in South Africa (Fedderke *et al.* 2006). Even in informal settlements, sufficient infrastructure is the key to unlocking settlement potentials for economic growth (Gnade *et al.* 2017; McRae 2015). These studies show the centrality of urban transport infrastructure investment in African cities. Studies by Chakwizira (2013) and Pirie (2013) provide strong evidence that African cities face aging and dilapidated transport infrastructure, traffic congestion, and inadequacy of policy links between transport and land use planning. Some of the factors behind the demand for urban transport infrastructure are the growing middle class, diverse transport system, and the informal transport system as elaborated in this section.

3.4.1 *Growing middle class*

Despite literature pointing to urbanization and poverty in cities of the Global South and SubSaharan Africa, many countries in the region have been experiencing a steady growth of the middle class. This class has demands for transport infrastructure that have emanated from their increased purchasing power, mobility, and use of private automobiles (Ndebele and Aigbavboa 2018). This growing sector, together with poor public transport has increased the use of private car ownership. For example, Mbara (2002) noted that African cities have one of the highest rates of annual traffic increases, ranging from 15% to 20%. These demographic changes and increasing car ownership and mobility have increased the demand for urban transport infrastructure.

3.4.2 *Informal transport systems*

Urban informality, and in this context, the informal transport industry is inseparable from urban development discourse in the Global South and Africa. Middleton (2016) observed that 72% of daily trips in Johannesburg and 90% of daily trips in Nairobi are made via informal transport systems (taxis, minibuses, or matatus). These informal transport systems are also dominant in cities across Botswana, South Africa, Lesotho, Zambia, and Zimbabwe. The informal transport industry serves as a crucial public transport service in Gaborone, Johannesburg, Maseru, Lusaka, and Harare. This is critical considering that state-owned transport systems are either non-existent or ineffective (Ndebele and Aigbavboa 2018). Moreover, this informal transport sector is ineffectively regulated (Middleton 2016). As a result, adequate planning and management of urban transport infrastructures are affected by the unregulated informal transport industry.

3.4.3 *Challenges in urban transport infrastructure financing*

The financing of urban transport infrastructure in Southern Africa has suffered from divergent interests amongst funders. Often this competition is between the neoliberal 'Washington Consensus' by the World Bank seeking public-private partnerships (PPP) towards attracting private finance and the state-capitalist 'Beijing Consensus' by China through its Belt and Road Initiatives (BRI) (Anguelov 2021). Over and above these global funding mechanisms, individual states have been playing a significant role in financing road infrastructure as shown in the Gauteng Rail Transit System. Jiang (2019) for instance argues that the Keynesian development state has been on the rise following the financial crisis and the weakening dominance of the neoliberal economic model. Nevertheless, the Chinese Belt and Road Initiatives in Africa have been criticized for their neo-colonialist approach of scrambling for natural resources, exporting cheap products, and questionable labour and environmental standards (Jiang 2019). However, those supporting the Chinese infrastructure development model argue that this is an alternative development paradigm that is based on a sustainable business approach, thwarting the aid-driven social programs that are tied to poverty alleviation (Brautigam 2009). Besides its many challenges, the Chinese model could be a welcome alternative, since many infrastructure projects in Africa are heavily dependent on donor funding (Turok 2016).

4 DISCUSSIONS AND IMPLICATIONS

There is growing evidence of the critical role of transport infrastructure in the development of the Global South and African cities and economies. However, challenges have been identified that should be tackled by policymakers, practitioners, and researchers towards improving urban transport financing. This section discusses the policy, practice, and research implications of this study. Besides the efforts in investment in transport infrastructure noted above, a huge gap still exists, as demand for infrastructure outweighs supply. Globally, literature shows that in most emerging economies, infrastructure development is declining below the estimated optimum requirement of 5% of the GDP per annum (World Economic Forum 2014). The African Development Bank (AfDB) further estimates that the continent's infrastructure finance gap ranged between \$68 and \$1048 billion in 2018 (AfDB 2018). In addition, the United Nations (2015) observes that 60% of Africa's population lacks access to basic infrastructure. As a result of this low investment, Africa has insufficient infrastructure, regional links, and limited household access (Musonda *et al.* 2019).

Moreover, Turok (2016) observes that transport inefficiencies and congestion add to business costs that threaten city competitiveness. This is supported by Magwendere and Marozva (2023) who argue that Africa's poor road, rail, and harbour facilities contribute up to 40% of the cost of its tradable goods. Moreover, many African cities experience poor internal mobility as well as poor external connectivity (World Bank 2009). As a result of the foregoing, many African governments have prioritized urban transport infrastructure development in line with the African

Union's Agenda 2063 which prioritizes the development of Pan-African infrastructure that includes high-speed trains (African Union 2021). Despite these infrastructure gaps, African urban populations are growing at an average rate of 4% to 5% per year, increasing the demand for urban transport services (Pirie 2013). Thus, governments and private individuals should continue to work together to create a conducive policy environment as well as practical interventions to promote urban and economic development in Southern Africa which will target urban centers.

This study contributes to the discourse on urban transport infrastructure investment and highlights the importance of transport infrastructure towards economic growth and urban development

(Cirolia *et al.* 2021; Jiang 2019; Ndebele and Agibavboa 2018). It also shows data gaps in development interventions by major countries such as China and India. Therefore, detailed country and city-specific case studies should be carried out on urban infrastructure financing to capture detailed narratives to support policy formulations and interventions. Besides addressing knowledge gaps, studies could also present real-world solutions, capturing informal transport systems and how they can be included in the planning and management of present and future urban infrastructure requirements. Thus, there is a need for dialogue between policy, practice, and research towards evidence-based policy and interventions.

5 FINANCIAL POOLING MECHANISM FRAMEWORK

The study recommends the framework described in Figure 5 which entails the comprehensive framework recommended for the Southern African countries. This is tailored to incentivize strong financial pooling mechanisms for sustainable urban transportation infrastructure development in the Southern African Development Community (SADC). Additionally, this model can be adjusted for use in the SADC and other African countries.

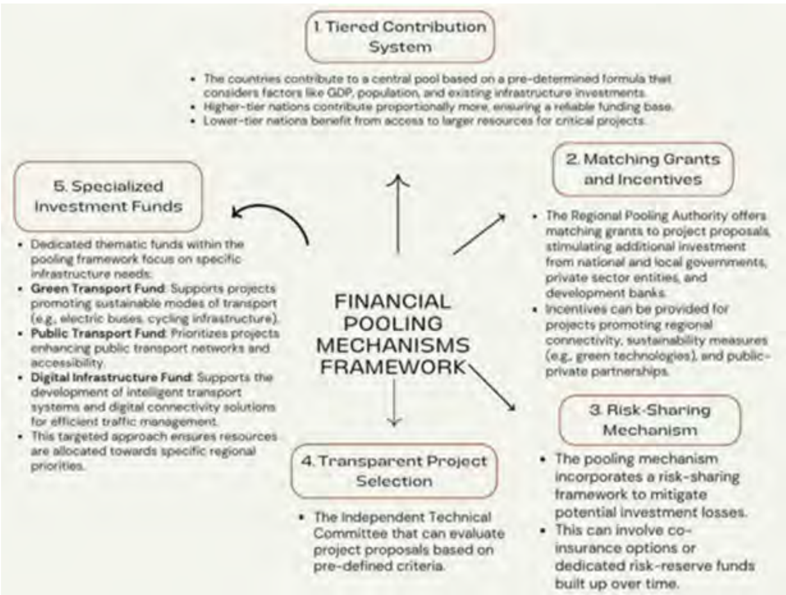

Figure 5. Financial pooling mechanisms framework [Source: Authors, 2024].

The expected outcome, if this model is applied, could lead to increments of investment in Southern African countries as selected by the study. Pooling resources will allow mega-projects that potentially will not be feasible for individual countries. For that, the framework recommends collaborative efforts from these countries. The framework potentially will provide diversification of funding sources and is an alternative to traditional funding sources which can attract private sector investments at a global scale. Harmonizing regulations between the Southern African countries to ensure compatibility in project development across the subjected countries as the study will be challenging as the framework suggests that higher-tier countries will contribute proportionally more than others towards the central pool.

6 CONCLUSION

Cities of the Global South in general, and Southern Africa in particular, are rapidly urbanizing but still faced with a huge gap in corresponding urban transport infrastructure investment. This has created a demand for transport infrastructure, given its clear relationship with economic growth and quality of life. Urban transport infrastructure is funded through international development banks, government grants, the private sector, and recently through resources-based lending. Nevertheless, there are criticisms for the effectiveness of aid-based loans as well as the exploitative nature of resource-based loans. However, this offers Southern African countries alternatives with which to pool resources. Cities of Southern Africa are facing increasing car ownership, and road congestion from the growing middle class which has an increased purchasing power and mobility, as well as a large informal transport system that is unregulated. These combined factors present challenges to the provision of public transport systems and transport infrastructure and supporting policies. More research is therefore needed to provide evidence upon which relevant policies and practical interventions can be tailor-made towards pooling resources for urban transport investment. Studies have reviewed urban transport financing in Africa as well as globally (AU 2021; Anguelov 2021; Jiang 2022; Middleton 2018; Ndebele and Aigbavboa 2018). This study focuses on Southern Africa where mega urban infrastructure initiatives have improved inter and intra-city connectivity and integration. However, this study limitations lies in literature search which identified relevant publications in English language only. This implies the omission of some potentially important work that was only available in other languages, especially on urban transport infrastructure funding initiatives from China and India.

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Theme 4: Digitalisation in the built environment

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Drivers for Building Information Modeling (BIM) implementation in the Malawian construction industry

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ABSTRACT: There has been a rise in the adoption of BIM in recent years. However, developing countries, including Malawi, are taking long to adopt it. Therefore, the study aimed to increase the adoption of BIM within the Malawi construction industry by investigating the factors that drive its implementation. A quantitative methodology was employed, identifying 13 BIM implementation drivers through extensive literature review. 189 questionnaires were collected using an online survey. The collected data was analyzed using the Relative importance index. The findings revealed that all the drivers were critical to implementation; however, the most impactful included but were not limited to improving project visualization, better storage of design data throughout the entire built asset's lifecycle, and helping with accurate quantity take-off and cost estimation. The study concluded by recommending that all industry bodies, government, educational institutions, and other construction-related stakeholders work together to improve and bring digitalization to the industry.

Keywords: BIM, Construction industry, Drivers, Malawi, Implementation

1 INTRODUCTION

The construction industry contributes hugely to the global economy. The sector now makes up 6% of the worldwide gross domestic product (GDP) and is expected to increase to 14.7% by 2030 (Global Construction Perspectives and Oxford Economics 2015; World Economic Forum 2018). It is divided into several sectors, and research has defined it as a fragmented industry (Alashwal *et al.* 2011; Hove 2016). These sectors include transportation, construction, solid waste, etc. Also, projects in the construction industry consist of several phases: preparation and briefing, concept design, spatial coordination, technical design, manufacturing and construction, handover, and use (Alnaggar and Pitt 2019). According to Gamil and Rahman (2017), communication must be at the highest level between stakeholders and move down to the labour force to improve efficiency in this complex industry. If communication is not facilitated, failure in planning, delays, and cost overruns become common in projects, and perhaps even more than success. Thus, in recent years, the focus has shifted towards digitalization and adopting new digital trends to improve productivity (Maskuriy *et al.* 2019).

While the sector is changing, the progress in digitalization is slow. This industry lags in adopting modern technologies compared to several different industries, such as banking, manufacturing, and retailing (Parviainen *et al.* 2017). Although Gu and London (2010) highlight the underwhelming global uptake of Building Information Modelling (BIM) in the construction sector, Safour *et al.* (2021) highlighted that there has been an increased adoption of BIM in the past few years. Cutting-edge technologies such as three-dimensional (3D) printing, BIM, Internet of Things (IoT), artificial intelligence (AI), and other innovative tools are being introduced to address challenges and open up new avenues to enhance productivity and efficiency within the industry (Rane 2023; Saka and Chan 2019).

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The introduction of BIM is gradually changing the shape of the Architecture, Engineering, and Construction (AEC) industry. BIM is a digital technology that facilitates collaboration, coordination, and information sharing throughout the project lifecycle (Sacks *et al.* 2018). By enabling the creation and management of a virtual representation of a construction project, BIM integrates design, construction, and operational information, leading to improved project visualization, enhanced decision-making, and streamlined project processes (Hardin and McCool 2015). Erri Pradeep *et al.* (2019) add that BIM involves information and model exchange among project stakeholders/collaborating teams.

Ghaffarianhoseini *et al.* (2017) state that BIM emerges as a solution to the vast challenges deeply rooted in the construction industry, which come with the industry's dynamic nature and the complexities driven by clients' needs. The ever-changing nature of the construction industry calls for construction approaches that are dynamic and adaptable. This kind of response becomes crucial in addressing the diverse challenges faced by the industry, especially in developing countries such as Malawi. These challenges include but are not limited to poor project communication, lack of stakeholder participation, low productivity, and high error and rework rates (Chilipunde and Shakantu 2010). However, Saka and Chan (2019) emphasize that the knowledge and acceptance of digital construction methodologies and BIM practices in developing countries are the main obstacles to its slow momentum.

Given the modern complexities of construction contracts, architectural planning, and the increasing need for high-quality infrastructure development, construction firms face overwhelming challenges that technology can only easily overcome. Furthermore, BIM is not well-researched in Malawi. Therefore, this paper aims to identify the drivers influencing the adoption of BIM through an extensive literature review. It seeks to analyze the significance of these drivers in practice, considering the perspectives of Malawian construction professionals. Furthermore, this study addresses a knowledge gap in the existing BIM literature, where identified drivers for BIM adoption are acknowledged but not systematically prioritized in relative importance. The plan is to aggregate the identified BIM drivers and determine their comparative impact through the order of priority. This approach allows adopters to identify the key drivers influencing BIM adoption.

2 LITERATURE REVIEW

2.1 *BIM in the Malawi construction industry*

The Malawian construction industry is one of the smallest industries among the Southern African Development Community (SADC) countries. Despite its size, it employs various employees, ranging from unskilled to skilled. (Foster and Shkaratan 2011; Kululanga 2012). However, the industry must adopt innovative emerging technologies such as BIM and other integrated project management technologies (Adekunle *et al.* 2021). A key challenge lies in the country's lack of awareness and technical knowledge of BIM, with studies indicating a below-average awareness level among construction professionals (Saka and Chan 2019). The lack of comprehension is due to government laws and policies, expensive implementation costs, software procurement concerns, and a general lack of knowledge (Ghaffarianhoseini *et al.* 2017). Moreover, the sector heavily relies on two-dimensional (2D) Computer-Aided Design (CAD) for architectural and Mechanical and Electrical drawings, with limited utilization of three-dimensional visualization, thereby missing out on critical functionalities offered by BIM, such as energy analysis, clash detection, and cost estimation (Al Sehrawy *et al.* 2021). With low awareness, the practical implementation of BIM faces challenges. Therefore, there is a pressing need to emphasize awareness creation and knowledge generation to boost actual implementation.

2.2 *Drivers for BIM implementation*

It is frequently argued that the substantial fragmentation and lack of collaboration in the AEC industry is one of the primary issues facing the construction industry (Butt *et al.* 2016).

These justifications are thought to be the most significant factors affecting project delivery time (Chirwa *et al.* 2011; Kamanga and Steyn 2013). To complete a project on schedule, involved stakeholders must collaborate well. Therefore, BIM provides a novel approach to resolving these difficulties by facilitating improved information sharing across the project life cycle and between project team stakeholders. BIM creates and manages information about a construction project throughout its life cycle (Shepherd 2019). It is one of the most widely used types of digital representation of the design and documentation of construction projects (Eastman *et al.* 2011). BIM creates a new model for the AEC industry and has the potential to improve efficiency and coordination, which subsequently reduces conflicts between all project stakeholders and enhances the success of completing projects on schedule.

Eastman *et al.* (2011) state that BIM allows storing all project-related data in a single location (cloud storage). This makes it easier to access various design components, which may reduce some of the variables that can cause project delays. Furthermore, Hardin and McCool (2015) claim that BIM helps in problem anticipation by visualizing the construction lifecycle of the project from the first to the last step. In other words, BIM reduces errors at different development/construction stages.

Furthermore, BIM technology is a breakthrough that significantly benefits the construction sector throughout the project lifecycle (Chong *et al.* 2016; Hardin and McCool 2015). BIM supports concurrent construction throughout the project's lifetime (Succar 2009). Rifai *et al.* (2022) add that BIM facilitates the project life cycle from the development stage to the initial conception stage to the design, construction, operation, and rehabilitation. Azhar (2011) adds that the use of BIM benefits the construction sector in the following ways: Cost estimation: Quantity measurements can be made with BIM software, and any modifications made during the design and construction stages can be automatically adjusted; Construction sequencing: BIM helps generate sequencing and coordinate fabrications, material orders, and delivery dates; Fabrication drawings: developing fabrication drawings for various building systems becomes easy with BIM; and Detection design of conflict and clashes: A BIM model can identify conflicts and clashes between a structure's components.

BIM also minimizes the risks of ineffective communication for project managers by enabling all parties participating in construction projects to access the same version of data (Alagarsamy 2000; Rokooei 2015). According to Sacks *et al.* (2018), the main benefit of BIM in the pre-construction stage is quality and increased construction performance due to BIM's concept, feasibility, and design analysis. Benefits in the design stage of a construction project include improved energy efficiency and sustainability, more accurate visualizations of a design, automatic minimal corrections where necessary, modifications when required, the generation of 2D drawings, early collaboration among various design parties, and bill of quantities extraction. BIM also coordinates the planning phases of design and construction, detects design mistakes and omissions, uses design models as the foundation for fabricated components, and applies lean construction methods during the construction phase. Furthermore, BIM improves infrastructure management and operation throughout the post-construction stage. Various drivers propel the adoption of BIM as a technological innovation in the construction sector. A compilation of these drivers, as identified by multiple researchers, is displayed in Table 1.

Table 1. Drivers for BIM implementation.

Code	BIM Drivers	References
D1	Enhance collaboration and coordination	Azhar *et al.* 2008; Sacks *et al.* 2018; Shepherd 2019
D2	Improve project visualization	Hardin & McCool 2015; Zhao *et al.* 2022
D3	Shorten the overall project timescale	Hardin & McCool 2015; Zhao *et al.* 2022
D4	Improve decision-making	Hardin & McCool 2015; Zhao *et al.* 2022
D5	Reduce construction conflicts	Azhar 2011; Sacks and Barak 2010

(*continued*)

Table 1. Continued

Code	BIM Drivers	References
D6	Reduce overall project cost	Chong *et al.* 2016; Succar 2009
D7	Facilitate efficient constructability analysis	Hardin and McCool 2015
D8	Help with accurate quantity take-off and cost estimation	Azhar *et al.* 2011; Vieira *et al.* 2017
D9	Assist with full project lifecycle evaluations	Rifai *et al.* 2022; Sacks *et al.* 2018
D10	Make project scheduling easier	Azhar *et al.* 2008; Azhar 2011
D11	Provide clients with better value for money	Succer 2009
D12	Improved design analysis and appraisals	Eastman *et al.* 2011; Sacks *et al.* 2018
D13	Be a better storage of design data throughout the entire built asset's lifecycle	Eastman *et al.* 2011; Rokooei 2015

Note: D = Driver

3 METHODOLOGY

A comprehensive literature review was done to identify the knowledge gap regarding BIM drivers in the Malawian construction industry. A quantitative methodology was employed with a questionnaire survey as the data collection method, chosen for its efficacy in gathering objective and measurable data, a crucial aspect of this paper (Saunders *et al.* 2019). The questionnaire consisted of two parts to achieve the study's aim. The first part focused on the respondents' demographic information, and the second focused on BIM drivers. 189 questionnaires were collected. The respondents to the survey consisted of construction professionals such as engineers, construction managers, project managers, health and safety officers, architects, quantity surveyors, lecturers, and directors working under consultants, contractors, government, real estate, and educational institutions. The questionnaire was designed to determine the critical drivers for successful BIM implementation in Malawian construction. The identified drivers from the literature review were put into a table for respondents to assess their impact using a five-point Likert scale. A Likert scale is preferable for measuring respondents' opinions, attitudes, and perceptions (Likert 1932), which was crucial for the study. The data obtained was analyzed using the relative importance index (RII) to determine the impact of the factors representing the drivers of BIM implementation in the construction industry. The factors were ranked, with the top-ranked variables having more impact than the next.

The RII was calculated as follows:

$$RII = \frac{\sum W}{A \times N};(0 \leq RII \leq 1) \tag{1}$$

Where W is the weight (1 to 5) the respondents assigned to each factor. A, represents the maximum weight, which is 5 in this instance, while N indicates the total number of participants, 189 in this study.

The respondent's information is shown in Table 2. From the findings, it can be concluded that many respondents had a bachelor's degree or diploma or BTech or higher certificate. Hence, out of all the respondents in the survey, 38.62% represent them. Another significant percentage of the respondents, 23.81% of the sampled population, had a diploma certificate, and 22.22% had an honours degree or postgraduate diploma. From there, as the level of the qualification increases, the number of respondents possessing it decreases. With that said, 14.29% of the population had a master's degree, and only an insignificant percentage (1.06%) had a doctorate. 35.98% of the respondents had jobs as engineers (i.e., civil, mechanical, electrical, etc.). 16.40% of the respondents were working as Quantity Surveyors, 13.76% were Architects, 9.52% were directors of organizations, 8.99% were Construction Managers, 6.35% were Health and Safety officers, 6.35% were Project Managers, and the least were working as lecturers (2.65%).

A considerable number of the participants had years of experience between one and five years (1 – 5 years). Hence, this group was represented by 59.26% of the entire sampled population. 21.16% of the respondents had six to ten years (6 – 10 years) of work experience, 10.58% of the respondents had eleven to fifteen years (11 – 15 years) of work experience, while 4.76% of the respondents had sixteen to twenty years (16 – 20 years) of work experience. Only 4.23% of the respondents mentioned having over twenty years of working experience. Furthermore, most respondents worked as consultants. This is seen with the significant 35.45% of the entire population that represents them. Another significant number of the respondents worked for contractors. The contractors were represented by 35.45% of the whole population. To make up the 189 respondents that participated in the survey, the government employed 16.40% of the respondents, while an educational institution employed 6.88%, and 5.82% worked as developers or in real estate organizations. Also, the results revealed that most respondents worked in medium organizations (21 – 99 employees). This is evidenced by the 43.92% of the entire population representing them. While 25.93% of the population worked for large organizations (more than 100 employees), 22.22% worked for small organizations (5 – 20 employees), and only 7.94% of the sampled population worked for micro-organizations (1 – 4 employees).

Table 2. Respondents' demographic distribution.

Respondents Demographics	Category	Percentage
Qualification	Diploma	23.81%
	Bachelors/Equivalent	38.62%
	Honours	22.22%
	Masters	14.29%
	Doctorate	1.06%
Job	Engineer	35.98%
	Construction Manager	8.99%
	Construction Project Manager	6.35%
	Health and Safety Officer	6.35%
	Architect	13.76%
	Quantity Surveyor	16.40%
	Lecturer	2.65%
	Director of organization	9.52%
Experience	1-5 years	59.26%
	6-10 years	21.16%
	11-15 years	10.58%
	16-20 years	4.76%
	More than 20 years	4.23%
Workplace	Consultant	35.45%
	Contractor	35.45%
	Government	16.40%
	Developer/Real-estate	5.82%
	University/College	6.88%
Organization size	Micro (1-4 employees)	7.94%
	Small (5-20 employees)	22.22%
	Medium (21-99 employees)	43.92%
	Large (more than 100 employees)	25.93%

4 RESULTS AND DISCUSSION

From the drivers determined from previous literature, improved project visualization (RII = 0.766) reached the highest impact of factors driving BIM adoption in the Malawian construction industry. This factor was followed by BIM's better storage of design data throughout the entire built asset's lifecycle (RII = 0.759) as second. The top five drivers were completed by helping with accurate quantity take-off and cost estimation (RII = 0.751), improved design analysis and appraisals (RII = 0.746), and enhanced collaboration and coordination (RII = 0.744). The least impactful drivers were reducing construction conflicts and overall project cost with RII of 0.685 and 0.677, respectively. All the drivers that impact the implementation of BIM in the industry can be verified in Table 3. The findings mean that respondents perceive what BIM can do for them and their organizations as more impactful towards their will to implement it. Some critical drivers in literature, such as reducing costs, time, and improving decision-making, are not considered more impactful in the Malawian construction industry. This may be caused by the understanding/fact that BIM implementation requires a substantial initial investment, and once implemented, it takes time to get it right. Hence, the results prioritized drivers related to the prevailing technical challenges in the industry.

Table 3. The respondents' view on the drivers for BIM implementation in Malawi.

	RII	Mean	Std. Deviation	Rank
Enhance collaboration and coordination	0.744	3.72	0.845	5th
Improve project visualization	0.766	3.83	0.840	1st
Shorten the overall project timescale	0.713	3.57	1.006	10th
Improve decision-making	0.712	3.56	0.952	11th
Reduce construction conflicts	0.685	3.42	0.951	12th
Reduce overall project cost	0.677	3.39	0.997	13th
Facilitate efficient constructability analysis	0.733	3.67	0.905	8th
Help with accurate quantity take-off and cost estimation	0.751	3.76	0.878	3rd
Assist with full project lifecycle evaluations	0.733	3.67	0.887	7th
Make project scheduling easier	0.741	3.7	0.891	6th
Provide clients with better value for money	0.717	3.59	0.856	9th
Improved design analysis and appraisals	0.746	3.73	0.810	4th
Be a better storage of design data throughout the entire built asset's lifecycle	0.759	3.79	0.878	2nd

5 CONCLUSION AND RECOMMENDATIONS

The study aimed to identify BIM drivers through a comprehensive literature review and determine their order of impact through a survey. The survey data was collected from construction professionals working under the government, contractors, consultants, real estate, and educational institutions. This was deemed critical as these entities are at the forefront of the industry and are highly important when discussing the construction industry's future. The findings revealed that the most impactful drivers included but were not limited to improving project visualization, better storage of design data throughout the entire built asset's lifecycle, and helping with accurate quantity take-off and cost estimation. However, all the identified drivers have a significant impact, with a relative importance index ranging from 0.677 to 0.766.

These findings are essential to the Malawian construction industry, as they inform BIM awareness builders, implementers, software developers, etc., of what would drive the sector towards widespread BIM adoption. Thus, the study recommends that all industry bodies, government, educational institutions, and other construction-related stakeholders work together to improve and bring digitalization to the industry. Also, more research must be done to understand what BIM offers and how the Malawian construction industry can benefit through project piloting and other relevant, innovative methodologies. New policies, regulations, and standards incorporating BIM usage must be developed to allow organizations to adopt BIM efficiently.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

A BIM-based web model for building materials scheduling for the building construction industry

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ABSTRACT: The building construction industry continues facing challenges that affect project delivery, with traditional practices used for Building Material Scheduling (BMS) being one of them. Studies indicate that these practices are less efficient and prone to errors, negatively affecting project objectives. Building Information Modeling (BIM) presents a promising solution for addressing these challenges, proven through existing integrations. However, its adoption in BMS practices in the construction industry is still relatively low. This study proposes a BIM-based web model for BMS. The model was developed with JavaScript language and MongoDB using a web browser to extract data from the user input, compute the required building materials, store projects, and facilitate collaboration among the project teams. This information helps create a detailed plan for material delivery, storage, and usage on a project and is also critical in optimizing materials use and reducing waste while ensuring teamwork.

Keywords: Building materials, Building Information Modelling (BIM), Building construction, Material scheduling

1 INTRODUCTION

According to Kirchberger (2020) and Giang & Sui Pheng (2011), the building construction industry is critical in developing countries, contributing significantly to their GDP and creating employment opportunities. It generates economic activity by providing infrastructure, housing, and commercial buildings that support other sectors, such as manufacturing, transportation, and trade. In countries like Tanzania, the construction industry contributes over 10% of the GDP. Despite its contribution, the sector faces issues that include the low adoption of technology and the use of traditional practices (Elkhalifa 2016; Haabazoka 2019; Katende *et al.* 2011; Kirchberger 2020). The building construction industry faces significant project delivery challenges, including delays, cost overruns, quality issues, and the slow adoption of BIM technology (Ally and Makenya 2018; Jongo *et al.* 2019; Kikwasi 2013). Additionally, the building material scheduling practices used in the building construction industry are still traditional, leading to less efficiency (Hussin *et al.* 2013).

Building materials scheduling is carefully calculating the required quantities needed for a building project to create a detailed plan for their delivery, storage, and usage throughout the project timeline (Cartlidge 2017). Moreover, scheduling building materials is critical in optimizing materials use and reducing waste. It impacts the planning, procurement, and tracking of construction materials to ensure timely delivery and installation on the site (Gulghane and Khandve 2015).

Although Building Information Modelling (BIM) presents a promising solution for managing building information and improving project delivery challenges (Arayici *et al.* 2012), its adoption in building materials scheduling practices in building construction projects is still relatively low (Ally *et al.* 2014; Ally and Makenya 2018). BIM is a digital representation of a building's physical and functional properties, which has emerged as a crucial technology in the construction industry worldwide (Nawaz *et al.* 2021), due to its potential to improve project efficiency, reduce costs, and enhance collaboration among project participants (Arayici *et al.* 2012; Perumal and Bakar 2011). It enables various stakeholders to collaborate, visualize, and analyze the building project in a virtual environment, leading to improved decision-making and better project outcomes (Azhar 2011). However, there is a limited understanding of the effective integration of BIM to enhance building construction project outcomes through building material scheduling practices. Furthermore, several studies have explored how BIM can be integrated into various aspects of the construction industry to leverage its benefits in ensuring project efficiency and effectiveness. For instance, Wei *et al.* (2017), addressed budget inaccuracies, management issues, and material waste, (Na *et al.* 2021), focused on managing green building materials. At the same time, (Najjar *et al.* 2017) evaluated the environmental impact of building materials during the early design stage, and (Handayani *et al.* 2021), aimed at improving the construction waste management process. These studies provide evidence that BIM can effectively enhance project delivery in different areas of the construction industry and has gained significant global recognition. However, more research is needed on integrating BIM in building material scheduling, a crucial aspect of successful project delivery.

Likewise, several BIM-based software applications have been developed to perform construction estimation tasks using drawings such as Bluebeam and Navisworks. However, most of them focus on quantity takeoffs, preparation of bills of quantities, and other tender documents (*Quantity Takeoffs & Construction Estimation | Bluebeam*, n.d.), with a limited focus on breaking the measured quantities into subsequent materials. Moreover, these software require several system requirements to run, such as CPU and RAM (Kull 2012; *System Requirements for Autodesk Navisworks 2023 Products*, n.d.), imposing an extra burden on the user and limiting the adoption of BIM in practice. They also run locally on the computer where they are installed and store data on the computer system they run. This leads to a cost burden on the user and limits accessibility without computer systems while pausing a high risk of data loss due to virus attacks or other system failures, leading to low reliability. Hence, it is necessary to develop a BIM-based model for building material scheduling to address these challenges.

2 RESEARCH METHODOLOGY

The research methodology for developing the proposed model will be done in five steps, as shown in Figure 1. Step 1 involves reviewing the literature to identify the construction industry's critical problems, research gap, and BIM benefits and integrations. Step 2 establishes the model requirements, determining the technologies required to develop the model. Step 3 uses the needed technologies to construct a conceptual framework of the model, and the final step uses the required technologies following the conceptual framework to develop critical components and features of the model.

2.1 *Development of the BIM-based web model for BMS*

This illustrates the parts/components that work together to accomplish a specific task (Kitchenham *et al.* 2015), and discusses the model development. Figure 2 shows the system for the Bim-based web model, which was developed using web-based technologies, i.e., Hypertext Markup Language (HTML), Cascading Styling Sheets (CSS), and JavaScript.

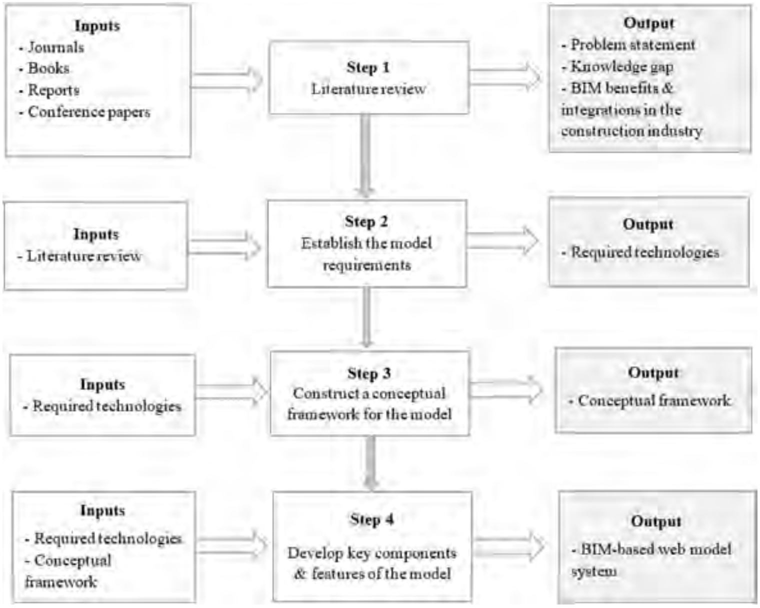

Figure 1. Steps for the research methodology. Source: Author's construct.

This will ensure that the model can successfully run without any need for system or compatibility requirements while ensuring real-time collaboration and cloud-based integration through the internet, which are critical features of BIM (Abruzzini and Abrishami 2022; Arayici *et al.* 2012; Chamari *et al.* 2022). The developed model is divided into two parts, i.e., the client and server sides, where;

The client-side is the user interface of a web application that is visible to the client or user and enables the user to interact with the application. It is also responsible for converting data from the server side into a format easily readable and navigable by the user through the graphical presentation (Alfonso *et al.*, n.d.; Malanchev and Matwey 2020; Peng and Xu 2021). This was developed using HTML as it is the most commonly used markup language for constructing web pages (Ali and Ahmad 2015; Specht and Zoller 2000), styled with Cascading Style Sheets (CSS) and powered with JavaScript due to its ability to allow user interaction and dynamic content rendering in the browser by manipulating the Document Object Model (DOM) (Khan and Mallika 2014; Wolf and Henley 2017).

The server side is the part of the web application responsible for what happens behind the scenes and is not visible to the user. It focuses on databases, backend logic, and servers, allowing the client side to communicate with the databases to store, retrieve, update, and delete data (Herdiyatmoko 2022; Phaneendra *et al.* 2022; Saldamli *et al.* 2021). This was implemented using MongoDB, a non-relational database due to its ability to handle big data and flexible schema management (Bhalla 2005; Liashenko and Dorosh 2021; Wang and Sharaf 2014; Zasuhina and Saharovskaya 2020), and NodeJS, a JavaScript runtime environment for the server (Low *et al.* 2014; Surhone *et al.* 2010).

The developed model allows user input in the web browser User Interface (UI), where the input data is used to generate building materials automatically using JavaScript logical functions. The project-related data in the browser can be exported locally to a spreadsheet file or sent to the database through an Application Programming Interface (API) for storage, easy sharing, and retrieval. The interaction between the server and client sides was implemented using Axios, a library for making promise-based Hypertext Transport Protocol Secure (HTTPS) (*Getting*

Started | Axios Docs, n.d.; Thomchick and Nicolas-Rocca 2018). The model's database consists of two schemas, i.e., the users and projects schema, as shown in Figure 2. Each model user has a unique username, ID, and password to distinguish users and their actions in the database, which helps protect the user information from unauthorized access. The project schema consists of the project title, creation date, creator (user), and associated computed building materials such as sand, cement, aggregates, bricks/blocks, etc., auto-computed from the user input data for the various elements of the building structure. Additionally, each project saved to the database has a comments array to allow react-time collaborations and reactions on the project by the project teams. This captures the comment message and the date and time a comment was submitted, which is crucial for record-keeping. This enables project teams to work together and make quick decisions, saving time and improving decision-making.

Moreover, the model has been developed to be accessed on all browsers and is fully responsive, making it easy for project teams to adopt, including those without computers. It also enables users to store project-related information on the cloud, ensuring data safety and easy access anytime and anywhere through the internet.

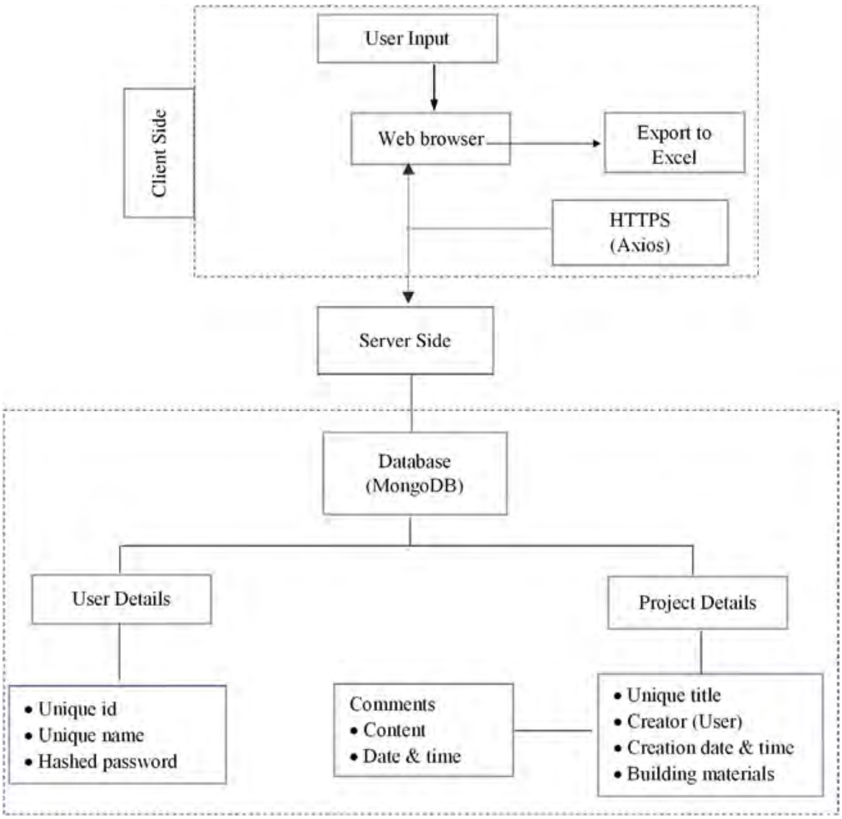

Figure 2. BIM-based web model system. Source: Author's construct.

3 BIM-BASED MODEL SYSTEM AND DISCUSSION

This section provides a detailed description of the functionalities of the different parts and layout of the developed Bim-based model for BMS. The model consists of four parts, i.e., authentication, user input, output, and information retrieval.

3.1 *User authentication*

The developed BIM-based model requires the user to be authenticated to access the functionalities, and the user is directed to a login page on the first load, as shown in Figure 3. The user must enter the registered username and password to log in. If this information is not entered correctly, a red warning message will be displayed, and the login button will be turned off, as shown in Figure 3. The model also allows the registration of new users who, after successful registration, can authenticate themselves with the registered credentials. This security measure ensures that user information is protected from unauthorized access, ensuring that the system is secure and confidential. After a successful authentication, the user is redirected to the model's main page, illustrated in Figure 3. The main/home page has a navigation bar with five tabs: Home, Projects, Contact, Feedback, and Logout. The Projects tab has links that redirect users to a new project window and projects saved on the BIM-based model database. The Contact tab allows users to contact the model administrator for technical assistance. The Feedback tab lets users provide general feedback about the model's operation, including areas needing improvement. Finally, the Logout tab allows users to log out of the model after work.

Figure 3. Login page for the BIM-based model. Source: Author's construct.

3.2 *User input*

In the new project window, there is a user form for inputting data on the items under different building elements, as shown in Figure 4. The user must input the amount of work required for each item based on the standard measurement methods applicable in the

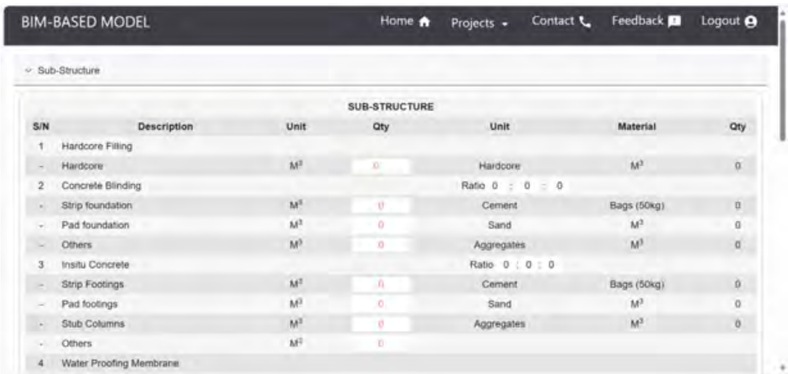

Figure 4. User input for the BIM-based model. Source: Author's construct.

building construction industry, such as cubic meters for concrete. The developed model is based on the Standard Method of Measurement (SMM) of Building Works for East Africa (Barker 1970). The materials, such as cement, sand, and aggregates, are auto-computed using logical functions, as discussed earlier, and displayed side by side with the input for larger screens and hidden for smaller viewports. This flexibility allows the user to only perform measurements on specific items of interest without any procedural requirements, as with most existing BIM-based software applications where almost every estimation process depends on quantity takeoff (Dang 2014; Liu *et al.* 2015; Zhang *et al.* 2020).

3.3 *Model output*

After data input, the results of the computed building materials are displayed on the output summary page, as shown in Figure 5. In the output summary, the user can export the results to an Excel file for local access on any device or save them to the BIM-based web model cloud database. Exporting data to Excel facilitates private information access, which is only available locally and cannot be accessed by the rest in the case of project teams. Storing each project in the model's cloud-based database provides centralized project information access, allowing easy access and collaboration among project teams. This is further discussed and illustrated in section 3.4.

3.4 *Information retrieval*

The projects saved to the cloud-based database are available to the user, as shown in Figure 6. A search bar is also available to help the user navigate through various projects in case many projects are saved. This helps to ensure that user information is protected from any potential system attacks and losses, thereby combating the deficiencies in the existing BIM-based software applications where user data can easily be lost, hardware theft, or other system failures, making it reliable at all times. In addition, the number of comments made on each project is shown. The user can also delete a specific project from the database by clicking the trash icon. The user can further view more information about a specific project by clicking on it, and details will be displayed. From this, users can also view and share comments on particular projects, leading to quick decision-making among project teams. By implementing these BIM aspects, easy information flow among project teams is made possible, facilitating collaboration and ultimately impacting project outcomes positively. Moreover, the stored project information can also be used as a reference for future related projects or, in case of any conflicts, serve as a vital tool for conflict resolution and benchmarking.

Figure 5. Output summary for the BIM-based model. Source: Author's construct.

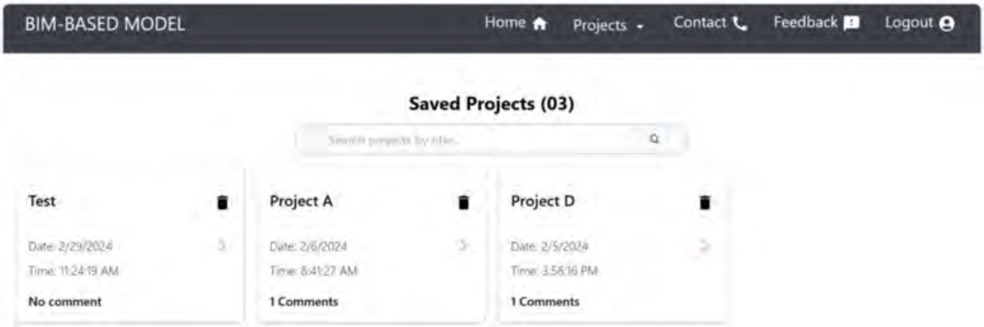

Figure 6. Project saved in the BIM-based model database. Source: Author's construct.

4 CONCLUSION

The study developed a BIM-based web model for building material scheduling using HTML, CSS, JavaScript language, and MongoDB as a database for storing project and user-related information. It includes input forms, projects' required building materials, and project-related comments from the various project teams stored in the model's database. All the information needed for the model is obtained from the user inputs to the forms under each building element using JavaScript. The unique ID is a permanent identifier for each user and their projects in the database. The study demonstrates BIM's potential to revolutionize building material scheduling practices by paving the way for enhanced efficiency, reliability, and collaboration in the construction sector through the developed web model.

The BIM-based web model will be extended to include user and project requirements changes throughout the building project's life cycle. This will ensure that the model updates the data stored in the database to match the current user requirements and project state.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Implementation of Industry 4.0 technologies in the maintenance of commercial buildings in Zimbabwe

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ABSTRACT: The aim of this paper is to explore the level of implementation of Industry 4.0 technologies in the maintenance of commercial buildings in Zimbabwe. Employing a quantitative method comprising questionnaires, data were collected from 70 participants consisting of Property Managers, City Council Authorities, and Private building owners. Through inferential statistical analysis, the study found the dominance of traditional paper-based maintenance practices. The study concludes that there are low adoption levels of industry 4.0 technologies in the maintenance of commercial buildings in Zimbabwe. Consequently, the study recommends the adoption of cyber-physical systems integrated with the Internet of Things, big data, and cloud computing in the maintenance of commercial buildings. Despite the small sample size limiting the generalisability of data, the results provide insights to improve the maintenance of commercial buildings which are in dire state in Zimbabwe and similar contexts.

Keywords: Industry 4.0 technologies, commercial buildings, maintenance, Zimbabwe

1 INTRODUCTION

Commercial buildings play a crucial role in economic activities worldwide (Nota *et al.* 2021). However, their contribution to socio-economic development of developing nations been hindered by poor maintenance (Gebhart *et al.* 2016). Traditional facilities management approaches used by most practitioners over the years have proven inefficient in maintaining commercial buildings thus far (Maskuriy *et al.* 2019). Scholars like Nota suggest that the adoption of modern technology can arrest the maintenance predicament facing most commercial buildings across the globe. Currently, the construction industry is lagging in adopting modern technologies, particularly in developing countries (Hermann *et al.* 2016). The low adoption seems to affect the longevity and functionality of commercial buildings, especially in the Zimbabwean context (Mujuru 2020). Gebhart and colleagues argue that the maintenance challenges characterising most commercial buildings in developing countries are largely attributed to outdated systems, inadequate funding, and low adoption of Industry 4.0 technologies. This is corroborated by Adelakun (2019) who posit that outdated infrastructure and limited resources challenge effective maintenance practices. While Adelakun suggests that Industry 4.0 technologies offer potential solutions the maintenance challenge, their implementation in building maintenance in Zimbabwe remains underexplored. There is a dearth of literature regarding the level of implementation of industry 4.0 technologies within the Zimbabwean context. Therefore, this study aims to fill this gap by assessing Industry 4.0 adoption levels and factors impeding optimum adoption of such technologies in

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the maintenance of commercial building in Zimbabwe. The findings provide insights to stakeholders to improve maintenance practices and policy decisions thereby enhancing sustainable commercial building maintenance in Zimbabwe and similar contexts.

2 INDUSTRIAL 4.0 TECHNOLOGIES IN THE CONSTRUCTION INDUSTRY

2.1 *The concept of Industry 4.0*

The Industrial Revolution, spanning from the late 18th to the early 20th century, marked the transition from agrarian to industrial economies (Veza *et al.* 2015). Triggered by innovations like the steam engine and electricity, it revolutionised production methods and led to societal transformation (Schwab 2017). The First Industrial Revolution, powered by steam, introduced mechanical production (Pereira and Romero 2017). The Second Industrial Revolution, driven by electricity and the combustion engine, enabled mass production (Atkeson and Kehoe 2001). The Third Industrial Revolution, initiated in the 1960s, was characterized by the advent of semiconductors, mainframe computing, personal computing, and the internet, ushering in the digital age (Mohajan *et al.* 2019). Industry 4.0, originating from Germany's high-tech strategic plans in 2011, revolutionises production through digitalization and connectivity. It integrates technologies like IoT, smart sensors, and AI, enhancing productivity and enabling real-time intelligence utilisation (Teizer *et al.* 2017). This paradigm shift connects humans, machines, and information, fostering future value creation. Industry 4.0 extends beyond manufacturing, impacting construction, healthcare, and more (Schwab 2016). Key components include CPS, IoT, AI, and big data, enabling seamless digitization and value chain integration (Hermann *et al.* 2016).

2.2 *Key technologies of Industry 4.0*

Contemporary technologies collectively form the backbone of Industry 4.0, driving digital transformation and innovation across industries (Mohajan *et al.* 2019; Hermann *et al.* 2016). By integrating these technologies into their operations, organizations can enhance efficiency, productivity, and competitiveness in the digital age. However, challenges such as cybersecurity, data privacy, and infrastructure limitations must be addressed to realise the full potential of Industry 4.0 technologies (Teizer *et al.* 2017). These technologies include mobile devices, IoT/IoS, BIM, CPS, big data, AI and cloud computing (Lee *et al.* 2021). According to Schmidt *et al.* (2015), IoT/IoS interconnects machines, products, and systems, enabling seamless communication and data exchange. BIM, as defined by Lee *et al.* (2021), facilitates comprehensive data management throughout the building lifecycle, enhancing design, construction, and facility management processes. CPS, described by Monostori *et al.* (2016), bridges physical and computational realms, enabling real-time monitoring and control of physical systems. Manyika *et al.* (2011), showcased that Big data extracts actionable insights from vast data pools generated by IoT and CPS systems, driving innovation and decision-making. According to Teizer *et al.* (2017), AI emulates human intelligence processes, offering predictive analytics and computer vision solutions to optimize construction processes. Cloud computing, highlighted by Giyane and Buckley (2016), provides scalable computing resources and enhances collaboration among construction stakeholders. 3D printing, as illustrated by Lim *et al.* (2016), enables the fabrication of customised building elements with precision and speed, fostering design flexibility and sustainability. Mobile devices, as highlighted by Dai, Bagozzi and Warshaw (2018), facilitate connectivity and real-time data exchange, enhancing decision-making and collaboration in industrial settings. Most of these technologies could be helpful in revolutionising the maintenance of commercial buildings in developing countries.

2.3 *Technology adoption models*

2.3.1 *Technology Acceptance Model (TAM)*

The TAM serves as a foundational framework in information systems and technology management, aimed at understanding individuals' acceptance and adoption of new technologies as previously noted by Dai, Bagozzi and Warshaw (1989). Recent studies have extended TAM to various contexts, including mobile banking, healthcare, and education, providing valuable insights into its applicability and relevance in understanding technology adoption behaviors (Alalwan *et al.* 2020; Al-Rahmi *et al.* 2021; Anwar and Rahman 2020; Dalvi-Esfahani *et al.* 2020; Tarhini *et al.* 2021). These studies emphasize the importance of perceived usefulness (PU) and perceived ease of use (PEOU) in influencing individuals' intentions to adopt technology. Additionally, external factors such as organizational support, trust, and self-efficacy play significant roles in shaping attitudes and adoption behaviors (Alalwan *et al.* 2020; Al-Rahmi *et al.* 2021; Anwar and Rahman 2020; Tarhini *et al.* 2021). While TAM provides a valuable framework for understanding technology adoption, it's crucial to ensure alignment between individuals' intentions and actual usage behaviors by addressing barriers such as perceived complexity and compatibility issues (Davis *et al.* 1989; Dalvi-Esfahani *et al.* 2020).

2.3.2 *Diffusion of innovations theory*

The Diffusion of Innovations Theory, originating from Everett Rogers in 1962, explains the spread and adoption of new ideas, technologies, or practices within societies. It's applicable at organizational, community, and global levels, focusing on factors like time, communication channels, and social systems (Rogers 2003; Taherdoost 2018). The model integrates adopter characteristics, innovation attributes, and the innovation decision process, highlighting factors like relative advantage and compatibility (Rogers 2003). Adopter categories include innovators, early adopters, early majority, late majority, and laggards (Rogers 2003; Taherdoost 2018). While it emphasizes system and environmental factors, it may have limitations compared to other models in predicting outcomes.

2.3.3 *Unified acceptance and use of technology theory*

Based on concepts such as Technology Acceptance Model (TAM), the theory emphasises user attitudes, perceptions, and contextual factors in determining technology adoption and utilisation (Venkatesh *et al.* 2003). In the context of commercial buildings maintenance in Zimbabwe, stakeholders' perceptions of Industry 4.0 technologies are crucial for successful implementation. Davis, Bagozzi and Warshaw (1989) stress the importance of perceived usefulness and ease of use in driving technology acceptance, while Venkatesh *et al.* (2003) highlight the impact of social influence and organizational support. Addressing barriers such as perceived complexity and compatibility issues (Rogers 2003) and fostering trust through robust cybersecurity measures (Gefen *et al.* 2003; Pavlou and Fygenson 2006) are essential. By considering these factors, stakeholders can promote technology adoption and realize the full potential of Industry 4.0 in commercial buildings maintenance.

2.4 *Level of adoption in developing countries*

The adoption of Industry 4.0 technologies in developing countries varies. Rwanda has positioned itself as a regional leader in technology adoption, driven by government initiatives and investments in digital infrastructure (Bowman 2023). Bowman confirms that Vision 2050 and initiatives like the Smart Rwanda Master Plan and Kigali Innovation City project demonstrate Rwanda's commitment to digital transformation. Industry 4.0 technologies, such as IoT-enabled sensors, predictive analytics, and digital twins, offer opportunities for enhancing commercial building maintenance (Teizer *et al.* 2017). In South Africa, the dominance of Real Estate Investment Trusts (REITs) and listed property funds in the commercial property market sets the stage for the integration of Industry 4.0 technologies in building maintenance (Hubner *et al.* 2022). In fact, Hubner, Moghayedi and Michell (2022) demonstrate that South Africa has embraced industry 4.0 in its economic development strategy to redress the existing low adoption levels. On the other hand, Nigeria is seen as Africa's economic hub and has seen a surge in initiatives aimed at integrating digital technologies like IoT, AI, and Big Data Analytics into various sectors, reflecting the growing recognition of their transformative potential (Adekoya *et al.* 2024). While signs of progress and varying levels of adoption across these countries exist, there are numerous impediments retarding technology adoption in most developing countries.

2.5 *Industry 4.0 implementation challenges in developing countries*

Muzenda *et al.* (2020) identified the major barriers of technology adoption limited access to capital for technology infrastructure investment, a shortage of skilled personnel proficient in digitalization, and resistance to change within traditional organisational structures. In support, Dhliwayo, Musonda and Gumbo (2023) highlight the lack of capital for investment as a significant challenge, particularly for Small and Medium-sized enterprises (SMEs). Scholars like Shan *et al.* (2020) argue that inadequate data infrastructure appears to thwart the implementation process, while Ahmadi *et al.* (2020) posit that the prevalence of poor data quality exacerbates the implementation challenge. However, Lee *et al.* (2019) contend that the lack of organisational interest in change, scarcity of skilled experts, and ignorance of Industry 4.0 technologies are predominant challenges.

3 RESEARCH METHODOLOGY

This study employed a quantitative approach to collect data using a self-administered closed and opened survey questionnaire tool. According to Creswell (2014) quantitative design seeks to systematically collect numerical data, typically through structured instruments such as surveys or questionnaires, to quantify phenomena and examine relationships between variables. As supported by Lee *et al.* (2019) and Muzenda *et al* (2020), the quantitative design was deemed appropriate for the study as it enabled the researcher to gather data from a sample of 70 respondents. The study's target population comprised Property Managers, City Council Authorities, and Private Building Owners in Zimbabwe who randomly selected. The survey questionnaire enabled the study to probe data on level of awareness, level of adoption and challenges related to the implementation of industry 4.0 technologies. The instrument offered a balance between flexibility and standardisation, allowing for both open-ended and closed-ended questions as supported by Bryman (2016). This approach enabled the researcher to gather quantitative data efficiently and maintained a degree of control over the data collection process while also accommodating participants' diverse viewpoints and experiences. Data were analysed using descriptive statistics and inferential statistics such as relative importance index (RII) and mean scores which provided insights into the levels of implementation of Industry 4.0 technologies in the maintenance of commercial buildings in Zimbabwe.

4 RESULTS

4.1 *Response rate*

The study employed online questionnaires distributed via Google Forms following a pilot test of 5 questionnaires. Out of 120 distributed surveys, 70 were completed, resulting in a response rate of 58%. This response rate exceeds typical expectations for online surveys, which generally range from 20% to 30% as according to Creswell (2014). Saunders, Lewis and Thornhill (2018) indicated how response rates may differ depending on factors such as respondents' level of interest, perceived relevance of the survey topic, and their familiarity with the survey administration platform. The study observed varying response rates among different respondent groups, such as property managers, city council authorities, and building owners, which is consistent with literature findings. The response rate of 58% indicates strong engagement from participants and lends credibility to the study's findings.

4.2 *Demographic information of respondents*

Table 1 presents the respondents' demographic information regarding gender, age, educational qualifications, profession, and industrial experience.

As shown on Table 1, the gender distribution indicates a relatively balanced gender representation in the sample. Professionally, the participants represented a diverse range of roles within the industry. The most common professions included Property Manager (51%), City

Table 1. Demographic information of participants.

Category		Frequency	Percentage
Gender	Male	33	53
	Female	37	47
	Total	70	100
Profession			
	Property Managers	36	51
	City Council Authorities	30	43
	Private Building Owners	4	6
	Total	70	100
Work experience			
	1-5 years	28	40
	6-10 years	25	36
	11-15 years	7	10
	16-20 years	9	13
	25 + years	1	1
	Total		100
Education qualification			
	National certificate	1	3
	Diploma	8	24
	Bachelor's Degree	41	47
	Postgraduate	20	23
	Total	70	100

Council Authorities (43%) and Private Building owners (6%). Regarding educational qualifications, the majority of participants held a bachelor's degree, representing 47%, followed by diploma holders, represented by 24%, while those with postgraduate qualifications constituted 23%. Only one respondent had a certificate, representing 3%. In terms of work experience, the participants had varying levels of tenure in their positions. The majority (40%) reported having 1 to 5 years of experience, followed by 6 to 10 years (36%), and 15 to 20 years (13%). Fewer participants reported having 10 to 15 years or over 25 years of experience.

4.3 *Current state of implementation*

The current state of Industry 4.0 technology implementation in commercial building maintenance was assessed through questionnaire surveys administered to property managers, city council authorities and private building owners. According to Kagermann *et al.* (2013) indicates that while Industry 4.0 concepts have gained traction globally, their adoption in developing countries like Zimbabwe is still at a nascent stage.

4.3.1 *Level of awareness*

The survey conducted to assess the level of participants' awareness and usage of Industry 4.0 technologies among 70 respondents revealed a significant level of adoption, with 87% indicating usage. The overwhelming majority (99%) reported familiarity with mobile devices, reflecting their widespread use in various industries. Similarly, 96% indicated familiarity with IoT/IoS technologies, underlining the common understanding of these interconnected systems. However, while 67% reported familiarity with cloud computing, 33% expressed no familiarity, indicating room for improvement in adoption. Regarding BIM, 60% reported familiarity, yet 40% indicated no awareness, suggesting potential for enhancing understanding and utilisation. CPS familiarity stood at 41%, with the majority lacking awareness, highlighting a need for education. Similarly, 41% were familiar with big data analytics, but 59% were not, indicating a gap in understanding its applications. Approximately 43% reported familiarity with AR and wearables, and 53% with VR, while 49% were familiar with smart sensors. However, significant proportions lacked awareness in these areas, indicating a need for education and training. Regarding location detection technologies, 63% were familiar, but 37% were not, suggesting an opportunity for increased awareness and adoption. Overall, while some technologies enjoy widespread familiarity, others face

Table 2. Level of awareness of Industry 4.0 technologies.

Industry 4.0 Technology	Yes	No	Total
Mobile Devices	99%	1%	100%
Internet of Things	96%	4%	100%
Cloud Computing	67%	33%	100%
BIM	60%	40%	100%
Cybersecurity	41%	59%	100%
Big Data Analytics	41%	59%	100%
Augmented Reality and Wearables	43%	57%	100%
Smart Sensors	49%	51%	100%
Virtual Reality	53%	47%	100%
Location Detection Technologies	67%	37%	100%

challenges, emphasizing the importance of education, training, and awareness initiatives. The findings also highlight the need for greater adoption efforts and investment in technological infrastructure within the commercial building maintenance sector. By addressing these gaps, stakeholders can effectively leverage Industry 4.0 technologies to enhance efficiency, productivity, and competitiveness.

4.3.2 *Level of adoption*

The study revealed a varied adoption rate of Industry 4.0 technologies across sectors, with some companies embracing advanced methods like predictive maintenance and remote monitoring while others are in early stages of exploration. A notable difference exists in how firms implement these technologies, with 67% indicating incomplete adoption and 32.9% claiming full implementation. Focused interventions, legislative changes, and capacity-building programs are essential to accelerate technology adoption, realize Industry 4.0 transformative potential, and enhance competitiveness. Survey results highlight respondents‘ familiarity with specific Industry 4.0 technologies. Nearly all respondents (98%) are familiar with mobile devices, suggesting their widespread use for maintenance-related tasks. Similarly, a significant majority (96%) are familiar with IoT/IoS technologies, indicating recognition of their potential for enhancing maintenance processes. However, there’s room for improvement in cloud computing awareness (67% familiarity) and utilization. Sixty percent are familiar with BIM, yet 40% lack awareness, indicating a need for education and training. Approximately 41% are familiar with CPS, and big data analytics familiarity stands at 41%, indicating growing exploration of data-driven maintenance strategies. These findings underscore the evolving landscape of Industry 4.0 adoption in building maintenance, suggesting opportunities for further education, training, and technological integration. The study reveals a varied landscape of Industry 4.0 technology adoption in commercial building maintenance, with 67% of respondents reporting incomplete adoption and 32.9% claiming full implementation. Factors such as leaders’ understanding, and resource constraints influence adoption rates. While mobile devices (98%) and IoT/IoS technologies (96%) are highly familiar, awareness is lower for cloud computing (67%), BIM (60%), CPS (41%), and big data analytics (41%). The “Greater Extent” adoption category holds the highest Relative Importance Index (RII), indicating prevalence. The moderate Mean value (2.5) suggests overall moderate adoption, with 51.4% reporting adoption to a “Lower Extent.” However, the presence of respondents indicating “Greater Extent” adoption signals a positive trend. This highlights the evolving nature of Industry 4.0 adoption, emphasizing the need for further education, training, and technological integration to enhance competitiveness in the sector.

4.3.3 *Implementation challenges or barriers*

The study revealed several implementation challenges hindering the adoption of Industry 4.0 technologies in commercial building maintenance in Zimbabwe.The most significant of these challenges is the lack of financial resources, particularly small and medium-sized enterprises (SMEs), struggle to access the capital needed to invest in the infrastructure required for I4.0 technologies. This includes IoT devices, smart sensors, and cloud computing infrastructure essential for modern maintenance practices. Without adequate financial support, organisations face difficulties in effectively integrating these advanced technologies into their maintenance operations. Other challenges identified include the lack of skilled personnel proficient in digitalisation and expertise in data analytics, IoT integration, and cyber-physical systems. Furthermore, the study identified resistance to change to adopt digital innovation due to organisational culture, limited data infrastructure, low-quality data, and ignorance about Industry 4.0 technologies, as impediments to the implementation of such technologies.

5 DISCUSSION OF RESULTS

The study's findings on the implementation of Industry 4.0 technologies in commercial building maintenance in Zimbabwe offer valuable insights that resonate with existing literature on technology adoption challenges in developing countries. The results show that Industry 4.0 technologies have been lowly adopted in the maintenance of commercial buildings in Zimbabwe. One of the most significant barriers identified in the study is the lack of financial resources, a challenge that has been widely documented in the literature (Muzenda *et al.* 2020; Dhliwayo *et al.* 2023). Limited access to capital impedes organisations' ability to invest in the infrastructure and technologies necessary for Industry 4.0 adoption, hindering their competitiveness and innovation potential (Ahmadi *et al.* 2020). This financial constraint is particularly acute for small and medium-sized enterprises (SMEs), which often struggle to secure funding for technology investments, as noted by Shan *et al.* (2020). Without adequate financial support, organisations face difficulties in acquiring advanced technologies such as IoT devices, smart sensors, and cloud computing infrastructure, which are essential for modern maintenance practices in commercial buildings. Moreover, the study highlights the shortage of skilled personnel proficient in digitalization as another significant hurdle to technology adoption, which resonates with Lee *et al.* (2019). In many developing countries, there is a scarcity of professionals with the necessary expertise in data analytics, IoT integration, and cyber-physical systems, which are critical for leveraging Industry 4.0 technologies effectively. The lack of skilled workers capable of implementing and managing these technologies limits organisations' capacity to fully exploit the potential benefits of digital transformation in maintenance procedures. This shortage of skilled personnel further exacerbates the challenges posed by cultural resistance to change and organisational inertia, as identified in the study. Organisational culture plays a pivotal role in shaping attitudes towards innovation and technology adoption, and entrenched resistance to change can impede progress in adopting Industry 4.0 solutions (Porter and Heppelmann 2014). Addressing these challenges requires strategic interventions such as capacity-building programs, investment in education and training, and initiatives to promote a culture of innovation and digitalisation within organisations. By overcoming these barriers, organizations can maximize the transformative potential of Industry 4.0 technologies and enhance the effectiveness and efficiency of maintenance procedures for commercial buildings in Zimbabwe.

6 CONCLUSION

This study examined the level of implementation of Industry 4.0 technologies in the maintenance of commercial buildings in Zimbabwe. The study found that traditional paper-based maintenance practices still dominate, indicating low adoption levels of Industry 4.0 technologies in the sector. Despite the small sample size, the findings provide valuable insights into the challenges and opportunities for leveraging digital tools to enhance building maintenance practices. The study underscores the importance of adopting cyber-physical systems integrated with the Internet of Things, big data, and cloud computing in commercial building maintenance to improve efficiency and productivity. However, several implementation challenges hinder the widespread adoption of Industry 4.0 technologies, including limited financial resources, a shortage of skilled personnel, resistance to change, inadequate data infrastructure, and organizational readiness issues. The practical implications of these results are significant. Stakeholders in the commercial building maintenance sector need to prioritise investment in technology infrastructure, skills development, and organisational change management to overcome barriers and unlock the potential benefits of Industry 4.0 adoption. Strategic interventions, such as funding initiatives, capacity-building programs, and stakeholder engagement, are essential for fostering a conducive environment for technology adoption and driving sustainable development in the sector. Therefore, the results of the study could be used by policymakers, industry practitioners, and researchers to develop policies and or strategies for increasing the adoption of industry 4.0 technologies in the maintenance of commercial buildings. By adopting the referred technologies, stakeholders can improve the maintenance of commercial buildings, enhance competitiveness, and foster sustainable development in Zimbabwe and similar settings, particularly in Sub-Saharan Africa. Although the study provides valuable insights, the sample size and the context used could pose limitations in generalising the findings to different settings.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Preconstruction estimation predictions through digital twin functionality by integrating IoT-enabled BIM with real-time sensor data

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ABSTRACT: During preconstruction, forecasting construction estimations faces challenges due to conventional techniques lacking real-time data, resulting in imprecise forecasts. Integrating IoT-enabled Building Information Modeling (BIM) with real-time sensor data in construction projects confronts scalability and practical implementation challenges. While theoretical benefits exist, empirical evidence of successful implementations across various projects is lacking. To address this, digital twin capability needs enhancement using IoT and BIM technologies. This systematic review explores IoT-enabled BIM integration with real-time sensor data to improve digital twin functionality for construction estimation accuracy. By examining existing research and identifying gaps, insights into how IoT-BIM integration can enhance digital twin functionality are provided. This integration aims to improve project outcomes and streamline construction processes by providing more precise estimations during the preconstruction stage. The review seeks to develop solutions and design methods for integrating IoT-enabled BIM with real-time sensor data, offering valuable in-sights for the construction sector.

Keywords: IoT-Enabled BIM, Real-time Sensor Data, Digital Twin, Construction Estimation, Preconstruction Phase

1 INTRODUCTION

The construction industry faces challenges in terms of the accuracy in estimating construction costs and timelines during the preconstruction phase, leading to potential delays and cost overruns in civil engineering projects. Traditional methods of conceptual construction estimation often lack real-time data and insights, resulting in inaccurate predictions and eventually inefficient planning (Wang *et al.* 2017; Yu and Fu 2004; Yu W. and Lee Y. 2004). To address these challenges, there is a need to leverage advanced technologies such as Internet of Things (IoT) and Building Information Modeling (BIM) to enhance digital twin (i.e., IoT and BIM combined) functionality for more accurate conceptual construction estimation predictions at the preconstruction phase.

Previous studies have highlighted the potential of digital twin technology in facilitating real-time data transfer from physical environments to digital counterparts (Deng *et al.* 2021). In this regard, as it is presented in Table 1, the potential of digital twin technology in facilitating real-time data transfer from physical environments to digital counterparts offers a wide range of benefits, including accurate representation, intelligent decision-making, process optimization, decision support, and effective interconnection and communication. However, challenges exist in achieving high-fidelity digital twins that require greater integration with new sensor technologies to enhance functionality and improve reliability (Opoku *et al.* 2022). The concept of the digital twin of the built environment has emerged

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Table 1. Potential of digital twin technology.

The potential of Digital Twin Technology	Key Points
Real-time and Accurate Representation	Offers real-time and highly accurate digital representation of evolving physical entities or systems.
Korenhof *et al.* (2023), Khajavi *et al.* (2019)	Integration with real-time sensor data enables recording and analysis of real-time structural and environmental parameters, enhancing simulation accuracy.
Data Interaction and Intelligent Decision-making	Utilizes data interaction, information fusion, and intelligent decision-making to create a real-time intelligent closed-loop system.
Zhang *et al.* (2023), Suhail *et al.* (2022)	Enables collection and integration of data from multiple sources, such as sensory and historical data, for learning physical environment behavior and anomaly detection.
Value Addition and Process Optimization	Serves as real-time digital counterpart of physical systems, providing methods for controlling processes, optimizing designs, and adding value to physical components.
Liu *et al.* (2023), Li *et al.* (2020), Sun and Shi (2021)	Facilitates real-time data transfer between physical and digital entities, contributing to predictive maintenance and quality prediction and control processes.
Decision Support and Interaction Tu *et al.* (2023), Wong *et al.* (2022)	Assists organizations in decision-making processes by providing real-time data linkages for inspection, monitoring, and prediction of complex processes or systems.
	Offers conceptualization of task-technology fit for users, enabling real-time monitoring, historical analysis, predictive analytics, and simulation.
Interconnection and Communication	Establishes inter-twin and intra-twin communications, enabling free data exchange, dynamic mission cooperation, and efficient information aggregation across vast physical and virtual entities.
Tiril *et al.* (2021), Wang *et al.* (2023), Zhao (2023)	Bridges gap between real-world physical systems and virtual representations, facilitating geometric change detection and motion simulation.

with the ability to connect real-time sensor data to digital representations of buildings (Afzal *et al.* 2023).

Despite the potential benefits of digital twin technology, complexities in advancements have posed challenges for professionals and researchers (Brosinsky *et al.* 2023). The construction industry's ability to construct digital twin images of assets relies on the data measured and collected (Omrany *et al.* 2023). Moreover, while IoT-enabled BIM systems offer the potential to integrate real-time sensor data into digital twin models, there is a lack of understanding of how this integration can enhance digital twin functionality to predict more accurate construction estimation. The lack of comprehensive research on the integration of IoT-enabled BIM with real-time sensor data for conceptual construction estimation poses a barrier to optimizing preconstruction planning and decision-making processes in the construction industry. Accordingly, the integration of IoT & BIM technologies has opened new possibilities for advancing digital twin functionality in the construction industry, which invites for further research. There is a need to explore the integration of IoT-enabled BIM with real-time sensor data to advance digital twin functionality for conceptual construction estimation predictions at the preconstruction phase. By addressing this gap, construction professionals can leverage cutting-edge technologies to improve accuracy, efficiency, and decision-making in construction projects. This paper provides a systematic review with the aim to address this gap by examining the current state of research, identifying challenges, and proposing solutions towards IoT-BIM integration for improved construction services.

2 METHODOLOGY

The main objective of this systematic review is to explore the integration of IoT-enabled BIM with real-time sensor data and to develop solutions as well as design methods for integrating IoT-enabled BIM with Real-time Sensor Data to enhance Digital Twin functionality for construction estimation accuracy improvement. This systematic review adheres to PRISMA guidelines by retrieving 61 peer-reviewed journal articles, conference papers, and scholarly publications from key databases (e.g., Scopus, Web of Science) and search engines. It is also structured to provide a comprehensive synthesis of existing literature on the integration of IoT-enabled BIM with real-time sensor data for preconstruction estimation. Beginning with a clear research question and objectives, the review defines eligibility criteria and systematically searches multiple databases using defined search strategies. Study selection and data extraction are rigorously conducted, followed by quality assessment and synthesis of findings using narrative methods. The review discusses implications for construction industry practices, identifies methodological strengths and limitations, and proposes recommendations for future research, ensuring a thorough and transparent evaluation of the current evidence base. Descriptive analysis was employed for this study.

3 LITERATURE REVIEW

3.1 *Current functions and applications of IoT-enabled BIM, real-time sensor data, and digital twin in the construction industry*

The current functions and applications of IoT-enabled BIM, Real-time Sensor Data, and Digital Twin technologies in the construction industry have been the subject of significant research interest. Rasheed *et al.* (2020) highlighted the challenges and enabling technologies of Digital Twin from a modeling perspective, providing insights for stakeholders. Woodhead *et al.* (2018) discussed the evolution of the construction industry driven by disruptive technologies, emphasizing the transition to an IoT ecosystem.

Kaewunruen *et al.* (2021) emphasized the momentum gained by Digital Twins in the construction industry, marking a shift towards the information age. Qiu *et al.* (2023) explored the application of Digital Twin in intelligent factory logistics, aiming to enhance connectivity and agility in logistics operations. Mao *et al.* (2022) proposed a Digital Twin framework for lean management in construction, highlighting the potential of Digital Twin to enhance constraint management practices. Cavalieri and Gambadoro (2023) emphasized the importance of interoperability for Digital Twins to communicate effectively with physical systems and applications. Newrzella *et al.* (2022) also introduced a three-dimensional Digital Twin reference architecture model, addressing the cross-industry character of Digital Twin applications and emphasizing dependability and life cycle development benefits. Minerva *et al.* (2020) discussed the technical features and architectural models of Digital Twins, foreseeing the increasing importance of Digital Twins in the future. Hence, the above scholars' work showcases the diverse functions and applications of IoT-enabled BIM, Real-time Sensor Data, and Digital Twin in the construction industry.

3.2 *Development of digital twin models for various applications*

Zheng *et al.* (2022) defined Digital Twins as virtual representations of physical assets or processes enabled through data and simulators for real-time prediction and optimization. The research by Rasheed *et al.* (2020) introduced BIM digital twins for the assessment and development of residential buildings, showcasing the potential of Digital Twins in enhancing the design, construction, and performance evaluation of structures. Corral-Acero *et al.* (2020) also emphasized the role of Digital Twins in precision cardiology, enabling accurate diagnosis and prognosis. On the other hand, Hui Han *et al.* (2024) presented a Digital Twin construction method for molded parts following SARIMAX model (i.e. Seasonal AutoRegressive Integrated Moving Average with eXogenous). Stadtmann *et al.* (2023) also defined Digital Twins as physical assets or processes virtual representations enabled through data and simulators for real-time prediction and optimization, highlighting their role in providing continuous assessment and monitoring for informed decision-making and control in dynamic environments. Guo *et al.* (2023) focused on the design and research of a Digital Twin machine tool simulation and monitoring system to prevent accidental collisions. By utilizing Digital Twin technology, the study developed a virtual model of machine tools to detect and prevent accidental collisions, showcasing the potential of Digital Twins in real-time hazard prediction and risk management in industrial settings.

3.3 *Current challenges on integration of IoT-enabled BIM with real-time sensor data*

One of the critical challenges identified in relation to the integration of IoT-enabled BIM with Real-time Sensor Data, is the lack of awareness and knowledge about BIM and IoT technologies in the construction industry. This lack of understanding can hinder the successful integration of these technologies into construction processes (Gamil and Rahman 2019; Villa *et al.* 2021). Additionally, the literature indicated the need for enhanced in-formation security when integrating IoT-enabled BIM with Real-time Sensor Data. Ensuring data integrity, confidentiality, and protection against cyber threats is crucial to the successful implementation of the said technologies (Shahzad *et al.* 2022; Zheng R. *et al.* 2019). Moreover, challenges related to data management have been identified, viz dealing with real-time data analysis, event recognition, prediction, and action planning. Brazauskas *et al.* (2021) and Teisserenc and Sepasgozar (2021) affirmed that adoption of IoT devices poses substantial network and system challenges in handling real-time data analysis and action planning.

Indeed, concerning complex integration processes, the integration of IoT-enabled BIM with Real-time Sensor Data presents technical challenges due to the high heterogeneity of these technologies. Addressing the complexity of integrating these technologies requires specialized expertise and efficient data management strategies (Natephra and Motamedi 2019; You and Feng 2020). Likewise, challenges related to collaboration, lack of professionals in the field, and compatibility issues have been identified. Overcoming these challenges requires fostering collaboration among stakeholders, enhancing professional skills, and ensuring compatibility between different technologies and workflows (Liu *et al.* 2024; Moradi and Sormunen 2023). Integrating IoT-enabled BIM with Real-time Sensor Data offers opportunities to enhance sustainability and lean construction practices. However, challenges such as high initial costs, lack of collaboration, and compatible contractual frameworks need to be addressed for successful implementation (Evjen *et al.* 2020; Sepasgozar *et al.* 2021). Therefore, while the integration of IoT-enabled BIM with Real-time Sensor Data offers significant potential for advancing construction processes, several challenges need to be addressed to ensure successful implementation and maximize the benefits of these technologies in the construction industry.

4 DISCUSSIONS ON IDENTIFIED STUDIES

In this section, the review delves into comprehensive discussions regarding identified studies focusing on the analysis of the functions of IoT-enabled Building Information Modeling (BIM), real-time sensor data utilization, and Digital Twin technology, exploring solutions to advance Digital Twin functionality while comparing various approaches and methodologies.

4.1 *Analysis of the functions of IoT-enabled BIM, real-time sensor data, and digital twin*

The analysis of the identified studies on investigation relating to current functions of IoT-enabled BIM, real-time sensor data, and digital Twin in the construction industry, reveals a diverse range of applications and functions in the construction industry. Balasubramanian *et al.* (2024) highlighted the significance of Digital Twins in enhancing sustainability within the construction sector. Their study emphasized the role of Digital Twins in providing a comprehensive and dynamic representation of building projects, enabling real-time assessment and predictive capabilities for improved decision-making. Nan-Ni Bi (2023) proposed the integration of Digital Twin information with the BIM system to support research on building zero carbon emissions. This approach aims to bridge the gap between Digital Twins and BIM, enabling the assessment and correction of building completion information for sustainable construction practices. Furthermore, Tagliabue *et al.* (2021) leveraged Digital Twins for sustainability assessment in an educational building, introducing a sustainable Digital Twin (SDT) framework. In summary, the analysis of the identified studies underscores the versatility and potential of IoT-enabled BIM, Real-time Sensor Data, and Digital Twin technologies in the construction industry. These technologies offer opportunities for enhancing sustainability, optimizing project management practices, improving efficiency, and enabling real-time assessment and predictive capabilities for informed decision-making in construction projects.

4.2 *Solutions for advancing digital twin functionality*

The analysis of the identified studies reveals a comprehensive exploration of developing solutions and design methods for integrating IoT-enabled BIM, Real-time Sensor Data, and Digital Twin technology in the construction industry. To achieve mature Digital Twin applications for Architecture, Engineering, Construction, and Operations (AECO) practices, Afzal *et al.* (2023) examined the developments and applications of Digital Twins in the construction industry, highlighting the significance of data integrity, integration, bi-directional interoperability, non-technical factors, and data security. Piras *et al.* (2024) presented a Digital Twin framework for the built environment, focusing on key enablers to provide best practices for the AECO sector. Yitmen *et al.* (2023) discussed cognitive Digital Twins for facilitating Construction 4.0, emphasizing the challenges and opportunities for implementation. Table 2 deals with the practical implications of IoT-enabled BIM & digital Twins in the Construction Industry.

Table 2. Practical implications of IoT-enabled BIM & digital twins in the construction industry.

Issue	Key Points
Application of IoT in Construction Industry Kumar (2023)	Understanding practical IoT applications in construction is vital for integrating IoT-enabled BIM and real-time sensor data. Insights can inform the implementation of IoT tech to enhance preconstruction estimation predictions.
Digital Twin Reference Model Development Bevilacqua *et al.* (2020)	Application implications include risk detection, cost reduction, and operational efficiency improvement via digital twin integration. Implementing a reference model can enhance operator safety and overall business performance in construction.
Internet of Things in Construction Industry Revolution 4.0 Abdullah *et al.* (2020)	Understanding IoT's challenges and benefits is crucial for policymakers and practitioners. Educating construction professionals on IoT importance can aid successful integration with BIM and sensor data.
Digital Twin for Supply Chain Coordination in Modular Construction Lee and Lee (2021)	Implications include real-time monitoring, data analysis, and improved coordination in projects. IoT sensors' use for synchronization with physical assets can boost supply chain efficiency in modular construction.
Digital Twin: Vision, Benefits, Boundaries, and Creation for Buildings Khajavi *et al.* (2019)	Insights guide digital twin creation for building elements, improving monitoring and maintenance. Utilizing sensor data enhances building reliability and performance through digital twin technology.

Hence, the analysis of the identified studies emphasizes the importance of developing solutions and design methods for integrating IoT-enabled BIM with Real-time Sensor Data for advancing Digital Twin functionality in conceptual construction estimation predictions at the preconstruction phase.

4.3 *Comparison of different approaches and methodologies*

The analysis of the identified studies provides valuable insights into the comparison of different approaches and methodologies for integrating IoT-enabled BIM with Real-time Sensor Data to advance Digital Twin functionality in conceptual construction estimation predictions at the preconstruction phase. Rasheed *et al.* (2020) discussed the values, challenges, and enablers of Digital Twins from a modeling perspective, emphasizing the importance of computational pipelines, artificial intelligence, and big data cybernetics in bringing the promise of Digital Twins closer to reality. In addition, Schleich *et al.* (2017) focused on shaping the Digital Twin for design and production engineering, emphasizing the differentiation between the real workpiece, its abstract model, and the virtual representation for effective geometrical variations management. Moreover, Tao *et al.* (2019) presented a Digital Twin-driven product design framework, introducing a novel method for product design based on the Digital Twin approach. Lu *et al.* (2020) also reviewed Digital Twin-driven smart manufacturing applications, focusing on the alignment with a proposed reference model. Therefore, the analysis of the identified studies underscores the diverse approaches and methodologies for integrating IoT-enabled BIM with Real-time Sensor Data for advancing Digital Twin functionality in construction.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 *Conclusions*

This review focused on the integration of IoT-enabled Building Information Modeling (BIM) with real-time sensor data to advance Digital Twin functionality for conceptual construction estimation predictions at the preconstruction phase revealing several key insights. The review underscores the significant potential of these technologies in enhancing construction estimation by leveraging real-time data from construction sites. This approach offers improved accuracy in monitoring project progress, resource utilization, and risk identification, crucial for making informed decisions early in the project lifecycle.

Despite the promising benefits, challenges exist in implementing IoT-enabled BIM and real-time sensor data integration. These include technological complexities, data interoperability issues, and the need for robust cybersecurity measures. However, various solutions and design methods have been identified to address these challenges effectively. By integrating IoT-enabled BIM with real-time sensor data, construction stakeholders can harness Digital Twin functionalities to enable proactive risk management, optimize resource allocation, and enhance sustainability assessments during project execution.

The implications of integrating IoT-enabled BIM with real-time sensor data for Digital Twin functionality extend to improving collaboration and communication among project stakeholders. Real-time data sharing and visualization capabilities facilitate better coordination and transparency, fostering alignment of project goals and enhancing stakeholder engagement throughout the construction process. Overall, this integration offers substantial benefits for the construction industry by transforming how construction projects are planned, monitored, and executed, paving the way for more efficient and sustainable practices.

5.2 *Recommendations for further research*

Despite the valuable insights obtained through the systematic review, further research is invited to overcome the current challenges associated with integrating IoT-Enabled BIM with Real-time Sensor Data for advancing Digital Twin functionality in construction estimation predictions. Future studies should focus on enhancing real-time data integration capabilities within Digital Twins to ensure accurate and up-to-date information for construction estimation predictions; investigate the potential of machine learning algorithms for predictive modeling within Digital Twins to improve accuracy and efficiency in construction estimation processes; and implement a system for continuous monitoring and evaluation of Digital Twin functionality in construction estimation predictions to identify areas for improvement and optimization.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Advocating for facilities management through the various BIM dimensions

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ABSTRACT: Traditional facilities management has been marred with challenges in collaboration, information sharing visualization of designs, data storage, and data processing. This study, aimed to establish how BIM-enabled facilities management could be used. A systematic literature review approach was used to identify BIM-enabled Facilities management using the existing literature. The results indicate sectors in diverse economies can benefit from BIM enabled facilities management once they overcome challenges such as cost of implementation, training, upgrade of communication infrastructure, formulation of guideline and interoperability of software. Evidence from the literature further shows that BIM offers solutions to traditional F.M. challenges by enabling efficient and effective cost management, scheduling, visualization, resource optimization, and energy efficiency for the facilities manager through various BIM dimensions. Facilities managers can now get real-time information from BIM-enabled facilities to manage facilities efficiently and adequately. The study recommends embedding BIM in facilities management training curricula for construction related professionals.

Keywords: BIM, Facilities Management, Zambia

1 INTRODUCTION

Many facilities in Africa are old, under maintained or need refurbishment or renewal. The situation is not so different in Zambia particularly in old infrastructure built before the 1990s. This is more pronounced in public buildings which have taken a traditional approach to facilities management. Nonetheless, Zambia's growing infrastructure portfolio requires smarter facilities management. A facility is a place, amenity or piece of equipment provided for a particular purpose, e.g., health, education, office space, manufacturing assembly, etc. While it has been easy to determine the construction cost of such facilities, choosing the operational costs is usually challenging. Additionally, facility owners typically face challenges in assessing the condition of their facilities and forecasting maintenance needs and replacement costs (Borhani *et al.* 2017). This was the situation until the early 2000s when Building Information Systems (BIM) presented solutions to such predicaments. BIM is defined as an information technology-based approach that involves applying and maintaining an integral digital representation of physical and functional aspects of a building (geometry, spatial relationships and geographic information) of all building information for different phases of the project life cycle

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in the form of a data repository to support decisions during its life cycle (Chang *et al.* 2018; IIozor and David 2012; Khaleel and Hilal 2023). BIM coupled with facilities management (commonly referred to as BIM for facilities management) is the answer to determining the operational costs and needs of various facilities globally and Zambia inclusive. BIM has a wide range of applications in facilities management, including enhancing building performance, improving operations efficiency, and reducing costs (Brinda 2014) which can be used for infrastructure development. Additionally, Musarat *et al.* 2023) points out that BIM increases data availability for operations and maintenance personnel. BIM offers a digital solution, creating a central model of your building with all its data. This translates to better space allocation, fewer surprises during maintenance, and less downtime for facilities. Facilities management is an integrated approach to operating, maintaining, improving, and adapting buildings and infrastructure of an organization to create an environment that supports the organization's primary objectives or functions (Tezel and Giritli 2019) leading to development of both old and new infrastructure.

BIM, from its inception, has various dimensions, commonly 3D to 10D, though Arnal (2018) argues that for the BIM dimension progression to be put in perspective, we have to start from the beginning, thus adding the 1D and the 2D. The BIM dimension associated with facilities management is the 6D; however, with a complete understanding of F.M., one notes that throughout the BIM dimensions, there are aspects of F.M. that can be harnessed based on the information and processes that can be done at each dimension. However, Tsay, *et al.* (2023) cautions that information collected should be relevant to maintenance of facilities otherwise it may not be useful. Most authors discuss F.M., given the 6D. Any data that can be used for F.M., regardless of the dimension in which it can be found, should be harnessed to improve F.M yet most of Africa Zambia inclusive has remained in the traditional mode of FM. Most authors note that 80% of a facility's cost is spent during its operation and maintenance phase (Ashworth and Perera 2015; Boussabaine and Kirkham 2008), during which facilities management is conducted making this study important. Furthermore, Facility management (F.M.) costs make for the third largest tier of the costs of organizations after the costs of personnel and production assets (Parsanezhad 2019). This paper, therefore, presents the various uses that can be harnessed from the different BIM dimensions for F.M which if done traditionally are in efficient and ineffective in terms of cost, time, quality, and safety moreover more infrastructure development can be achieved using BIM for FM. Past research has focused on a single utility at a given dimension. This paper collectively presents these findings making the utility of BIM for FM more apparent.

The following section reviews the literature on the BIM and F.M. body of knowledge with a bias to opportunities and challenges that Zambia and many other developing countries can learn from. A brief discussion is given on BIM and F.M., specifically maintenance management. Before the conclusion, a section is presented on the various BIM dimensions and how F.M. can benefit from them.

2 BUILDING INFORMATION MODELING (BIM)

Traditional designs in the Architectural Engineering and Construction (AEC) industry were based on the 2-dimension length and width. Over time, this needed to be more technological bringing about BIM. This has been supported by the collaborative working of the design team. BIM is a process supported by various tools, technologies and contracts involving the generation and management of digital representations of physical and functional characteristics of spaces (Azhar *et al.* 2012). From an Operational perspective, BIM embeds essential product and asset data and a three-dimensional computer model that can effectively manage information throughout a project's life cycle (Parn *et al.* 2016). As intended in the BIM Handbook, building models are digital representations of buildings and building components containing attributes and parametric rules (Parsanezhad 2019). The BIM approach retains information in a digital format, resulting in easy updating, sourcing, and sharing of information (Lin and Su 2013). Furthermore, BIM creates a hub for managing building energy and resources at all stages throughout its life cycle (Shi *et al.* 2015).

Since the inception of BIM in 2000, numerous studies on BIM have been done from multiple perspectives. Notwithstanding, the Construction industry globally is lagging in BIM adoption (Wildenauer 2020), hence making the harnessing of BIM and facilities management benefits not apparent. Moreover, Sibani *et al.* (2021) argues that only a few studies have been done for F.M. from the BIM perspective. Nevertheless, Wong, Ge, and He (2018) conducted a study reviewing the literature on digital technologies from 2004 to 2017 and found the focus areas were BIM, reality capture technology, the Internet of Things and Geographic information systems (GIS) as the most used tools leaving a gap for further research on BIM for FM.

BIM transforms and digitalizes processes, increasing efficiency and effectiveness (Aminoff *et al.* 2016; Waqar *et al.* 2023). However, facilities managers argue that BIM models are not always practical because they do not always have the information needed or the massive volumes of knowledge, making the data exchange process tedious and overwhelming. (Matarneh S.T. *et al.* 2018). Nevertheless (Khemlani 2011) states that every constructed facility requires a bespoke BIM model, like an owner's manual, with authorizations for model updates corresponding to periodic repair or refurbishment works. BIM dimensions" or "Dimensions of BIM," shortened with a sequence of following numbers starting with three and ending with D for Dimensions. (often 3-D, 3D, or 3-D, herein after nD, $n > 2$) as used to show different BIM abilities or capabilities. Each dimension has a peculiar characteristic, as shown in Table 3. There are currently ten dimensions (D) of BIM, all designed with a specific focus, as shown in Table 3. From the various dimensions of BIM, it is evident that they offer several benefits that can be harnessed for the modelling such as through 4D modelling, project managers can visualize the virtual construction of any project, identify any associated risk and make more subjective decisions rather than objective decisions (Musa *et al.* 2016; Fernández 2023; Visartsakul and Damrianant 2023). Such uses bring about the possibility of other unidentified opportunities for BIM.

BIM has other benefits, such as consolidating information, enhancing collaboration (Waqar 2023), making data actionable, helping stakeholders understand how occupants will interact with the built environment before construction starts, and allowing designers to experiment with innovative workplace design. The demand for such benefits will only increase with technological advancement and client sophistication (Falor 2021). Most of the benefits mentioned earlier are released from the use of computer-aided design programs such as Auto CAD, Revit, and Autodesk. Waqar *et al.* (2023) note that sustainability is enabled by using sustainable technologies that can be BIM enabled. This presents an opportunity to be more sustainable in both new and old building. The next section discusses facilities management.

2.1 *Facilities management*

Facilities management can be defined as the tools and services that support the functionality, safety, and sustainability of buildings, grounds, infrastructure, and real estate. F.M. has six F.M. functions: energy management, emergency management, space management, F.M. project management, operations and maintenance management, and quality management (Dahanayake & Sumanarhard areas of F.M. Hard areas of FM deals with physical assets such as plumbing, wiring, elevators, and heating and cooling, while soft F.M. focuses on tasks performed by people such as custodial services, lease accounting, catering, security, and groundskeeping. It has been argued that F.M. integrates people, technology, processes and places. These can be decomposed into space management (space reporting, space inventory and cost data, space concepts), financial requirements (asset and life cost, commercial model data, cost sensitivity and design efficiency), F.M. personnel (BIM training, handover road map, post occupancy evaluation) (Ashworth and Tucker 2016) and

Technology requirements. Atkin and Brooks (2014) argue that a well-planned and implemented F.M. practice would enable organizations to deliver effective and responsive services, adapt their usage of spaces to their fundamental business activities, create competitive advantage over competitors and perfect their culture and image.

Traditionally, FM processes depended on manual systems, specifically before the advent of the World Wide Web and various computer software and hardware. It is known that the service life of any facility can be improved through facility maintenance, which is an aspect of facility management (Ko 2017). With the rise in ICT and digital technologies, there has been a shift to automated systems that offer promise for F.M. in terms of effectiveness and efficiency. Additionally, to achieve high-quality F.M., analytical, managerial, cooperative and professional services are needed (Lok *et al.* 2018). Digitization is necessary to ensure that aspects such as sound connectivity, which aids the work of F.M., are present (Lindkvist *et al.* 2021). The Internet of Things (IoT) has improved operational efficiency in AEC; therefore, F.M. can benefit from IoT. While the need for quality F.M. is known, challenges have often been reported with F.M.

According to Pataca, Dawood, and Kassem (2020) and ; Kamaruzzaman, Suznan, & Myeda (2023), challenges associated with F.M. include a need for more frameworks for delivering information, its validation and its utility in F.M. Further, in the integration of information, IoT management standards are needed to enable effective and efficient F.M. (Tang *et al.* 2019). Measuring performance in any activity is essential as it helps gauge whether performance is good or bad. F.M., performance measures could be faster-paced and characterised by diverse and fragmented performance measures (Amos *et al.* 2019), making it impossible to trace the effectiveness and efficiency of F.M. in place. Inefficiencies and cost deficiencies are other problems associated with F.M., even when digital systems have been utilised due to lagging information updates of F.M. systems (Wen *et al.* 2021). All the above challenges are summed up well as the most critical issues in implementing BIM for streamlining Facilities Management and operation (F.M. & O) activities are the lack of guidelines and efficient technologies for capturing BIM models of existing facilities, coping with non-consistent terminologies and taxonomies, requirements specification in BIM applications, and identifying which information and levels of detail desired by the FM&O teams (Parsanezhad 2014). The next section is the methodology used in this paper.

3 METHODOLOGY

A systematic literature review was conducted using accessible research papers published between 2014 and 2023, excluding editorial documents. The search engine used was Google Scholar for its comprehensive coverage, accessibility, and its ability to search from other data bases (Jacso 2005; Walters 2009). The primary reason for its selection was that it was the only available tool that was accessible to the researchers. The search retrieved 7,600 papers. These were later screened using the research focus in Table 1. Only relevant, peer-reviewed, and accessible documents were used. Some of the papers are reflected in the reference section. Once the papers had been downloaded, categories and subcategories of important content were formulated to guide the content analysis of the documents, as shown in Table 1. Furthermore, the relevant papers were used as reference to another related research. The categories of data used after the initial review of the literature are presented in the previous section. These are facilities management, building information modeling and sustainability. Table 1 provided a framework for extracting information systematically to answer the questions posed by the benefits of BIM in F.M., and Uses of BIM for F.M. A qualitative content analysis was used to extract the vital information and discuss the findings to put them in context, as shown in the sections below.

Table 1. Framework of the research.

Category	Subcategory
Year	2014-2023
Nature of issues	normal or special
Research focus	Uses of BIM for Facilities, benefits of BIM for F.M., BIM and F.M., Challenges of BIM
Research data collection method	secondary data,
Data analysis method	content analysis
The country used to collect data	worldwide

4 FINDING AND DISCUSSION

4.1 *BIM for F.M.*

BIM for F.M. is a new and growing research subject because it fulfills the informational needs of the operational phase of assets within digitalized project workflows (Wong *et al.* 2018; Losev and Losev 2023). BIM's value in F.M. stems from improvements to current manual processes of information handover, accuracy of F.M. data, accessibility of F.M. data, and efficiency increase in work order execution (Kassem *et al.* 2015). Table 2 shows the opportunities and benefits BIM

Table 2. Various BIM for F.M. benefits.

Lowe (2020)	Falor (2021)	Schwartz, (N.D.)	Ashworth & Tucker, (2016)	Parsanezhad (2019)
Provides more accurate capital planning.	Enhances building life cycle management.	Generates savings in facility upkeep, maintenance, and improvements	Direct data transfer	Improved service completion time
Effective collaboration among teams	Integration of BIM with maintenance management to have maintenance plans	Improves project efficiency and expedites delivery of results	Simulation, e.g., energy use, fire	Increased energy efficiency
Helps streamline maintenance and repairs	Ease of access and usage of information by F.M.	Reduces safety risks and clashes, which lowers passive change orders	Improved transition construct to operations	Increased revenue generation from leases and rentals
Reduced energy waste and carbon footprint	Helps attain sustainability goals such as energy use and water consumption	Offers greater predictability for facility maintenance and upkeep	Visualization of buildings for construction and investment	Reduced reactive maintenance
Supports the future role of facility management	Space management is made easy as spatial data is fed into BIM.	Provides a system of record and visibility for vital systems within the building	Faster cost and life cycle cost estimate capability	Efficient Material consumption: e.g., are fuel and material savings through less travel waste or
		Integrates with facilities management software and systems to automate processes	Improved space management	Reduced work order complement time and cost
			Improved asset maintenance response	more coordinated maintenance and cleaning procedures
			Reduced cost of insurance for buildings	
			Improved health and safety for operational F.M. tasks	

Table 3. BIM dimensions and their utility for FM.

DETAILS OF DIMENSION	FM utility (Existing and Prospective)
BIM 1D implantation of BIM protocols	
Develop laws and contracts at the organizational or country level and use collaborative projects. No complex management, poor information exchange	Hard copy FM
BIM 2D Collaborative workflows	
Hiring Management Solutions	Collaborative working
BIM 3D Digital Model (Visualization)	
Comprehensive model, General plans, Amount of work, Improved presentation, Existing conditions model, Scanning, Ground penetration Safety & logistics models, Animation, renderings & walk-throughs, BIM-driven prefabrication Laser-accurate BIM-driven filed layout	Visualization of facilities, new and old, easy sharing of documents
BIM 4D Time (1995)	
Facilitative programming, Temporal Planning Processes, Project phasing simulations, Lean scheduling, Last planner, just in time (JIT) Detailed simulation installation, Visual validation for payment approval, Risk management	Risk identification for scheduling of activities, planning of maintenance work.construction scheduling/coordination
BIM 5D Cost 2012	
Help calculate and adjust budget, Real-time conceptual modeling and cost planning, Quantity extraction support, and detailed cost estimates. Trade verifications (structural, electrical, mechanical, plumbing, etc.), value engineering visualization, quantity extraction, and prefabrication solutions (equipment rooms, MEP systems, unique architectural and structural elements).	Life cycle costs, Cost saving, Forecast Financially, Development of estimates through data manipulation, Reduced uncertainty of design information through visualization, Availability of historical data for F.M., Cost estimating
BIM 6D Sustainability/ Operations for F.M.	
Analysis of thermal performance and efficiency energetic, Conceptual energy tracking Detail energy analysis, Sustainable element tracking (LEED tracking)	Increased operational efficiency.Reduction of carbon emissionsEnergy savings, water utility, improved indoor quality
BIM 7D Operation & maintenance	FM utility (Existing and Prospective)
BIM (as built) information with operation approach and maintenance, Life cycle BIM strategies, BIM embedded O&M manuals, COBie data population extraction, BIM maintenance plans and technical support, BIM file hosting on lend-lease digital exchange system	O&M Optimization Practices, Cost Minimization, Time Minimization, Accessibility, Efficient Material Selection, Use of Renewable Material and Durability of facility
BIM 8D Health and safety	
During the project, maintenance Embed emergency plans and prevent security issues	Hazards Elimination, Legislation Compliance and Risk Assessment
BIM 9D Lean management philosophy	
Lean construction	Identify value in the facility, eliminate waste in maintenance processes, improve the quality of the facility, continuously improve improvement and efficiency, and improve data management, knowledge sharing, and communication.
BIM 10D Industrialized construction	
Modular and prefabricated construction	Collection of as-built data, accuracy of visuals,

(Ahuja *et al.* 2014); Control (Ganisena *et al.* 2015); (Musa *et al.* 2016), (Demirdögen *et al.* 2020); (Jerry *et al.* 2020); (Soliman *et al.* 2022), Oluatunji and Sher, (2014), August, (2020) provides for F.M. These range from planning, design visualization, cost mitigation, time management, collaboration, energy efficiency to sustainability. Despite its significant advantages in promoting and strengthening organizational competitiveness, BIM is not widely used in the F. M. industry due to various challenges (Aziz *et al.* 2020). Specifically, the challenges maligning BIM and F.M. include the need for long-term strategic aspirations, amelioration of data integration and interoperability issues, augmented knowledge, performance measurement and enriched training and competence for facilities managers (Borhani *et al.* 2017; Pataca *et al.* 2020; Kamaruzzaman *et al.* 2023). Additionally, Gunasekara, Sridarran, and Rajaratnam (2022) found that although F.M. procurement has improved, it still needs to be simplified to be efficient and is challenging due to a lack of digital innovations however the use of blockchain technology is proposed to overcome the afforementioned. Information exchange remains a significant challenge in BIM and facilities management (Matarneh *et al.* 2019; Tsay *et al.* 2023). BIM asset information Management challenges stem from BIM regulations and standards, inaccurate information exchanges, software interoperability issues and unclear requirement definitions. Those above are to be solved to enable BIM-FM integration (Jang and Collinge 2020). All of those above could be premised on the fact that BIM-FM studies are predominately technology and process-oriented, with less attention paid to people or organisational aspects (Asare *et al.* 2022). Cybersecurity risk is a concern in this digital age and is a lot more risky for F.M. due to breaches in various working areas of F.M., specifically people and processes, due to an over-reliance on technology (Ghadiminia *et al.* 2022).

5 CONCLUSION

Facilities management is a significant activity in the life of any building. Traditionally, FM was marred with collaboration challenges, information sharing, visualization of designs, data storage, data processing and the like. Today, BIM offers solutions to these F.M. challenges. BIM-enabled FM enables cost management, scheduling, visualization, sustainability, optimization of resources and energy efficiency for the facilities manager through various BIM dimensions. Developing countries like Zambia can harness these for better F.M. Designers, cost managers and facilities managers could use BIM at design, and in the management of facilities as required for better infrastructure development. Clearly facilities using BIM for FM have demonstrated superiority in efficiency and effectiveness of FM compared to those managed traditionally. Challenges still exist, such as the slow uptake of the BIM-enabled FM due to the knowledge gaps in F.M., lack of access and knowledge of required technology, performance measurement, age of buildings and lack of training. Future research could be directed towards implementing BIM-enabled FM and embedding the same in the training curriculum of facilities managers and other construction related fields.

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Theme 5: Quality & resilient infrastructure development

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Transformations and challenges in peri-urban areas: Lessons from a small rural town in Makhado local municipality, South Africa

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ABSTRACT: One of the challenges many countries in the global south face is managing the rapid peri-urban expansion into surrounding villages. In the past years, peri-urban expansion analysis has been experienced extensively in big cities. It has however through urbanisation, which is accompanied by globalisation, made its way into small rural towns. However, there is very little that is known about peri-urban expansion in small rural towns. Consequently, this paper examines the complex issues related to spatial planning, service delivery, and governance concerns in Makhado Biaba town in South Africa. The work adopted a mixed methods research approach, which employs both quantitative and qualitative research approaches. Findings show that there are various issues influencing the livelihoods of the rural communities surrounding the small rural town of Makhado local municipality.

Keywords: peri-urban, small rural town, space production, Makhado Biaba Town, governance

1 INTRODUCTION

Peri-urban areas have been described as spheres of coexistence of the urban and rural activities (Douglas 2006). Ideally, this coexistence is meant to offer unique opportunities for both rural and urban land use functions, therefore, mixed land use. There is no universal definition of peri-urban areas. Certainly, they are difficult to identify due to the unusual variety and dynamism (Melo and Jenkins 2021). A peri-urban area is a zone of contact between urban and rural characterised by material and immaterial relationships, where a system of functional, socio-economic, spatial and eco-systemic relations is recognisable between rural areas and urban areas (Zasada *et al.* 2011). Peri-urban expansion analysis has been growing in leaps and bounds for more than decades now (Patra and Chowdhury 2021; Onyebueke and Geyer 2011). Makhado Biaba Town consists of nine villages, and five villages were selected purposively and conveniently to participate in the research (Makhado IDP,2022/23-2026/27). Land administration of the peri-urban villages of Makhado Biaba

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town are administered by local traditional leadership, chiefs, and village headman. They act as the central institute in land governance, specifically for allocating land tenure rights in terms of Permission to Occupy (PTO) on behalf of governmental bodies such as the state and local municipalities (Ingwani 2021). Rapid urbanisation is significantly transforming peri-urban areas, creating complex challenges that affect socio-economic and land use governance (Nkosi *et al.* 2022). Understanding these transformations is crucial for sustainable development and policy formulation. This study seeks to assess the dynamic changes and challenges faced by rural peri-urban areas as a consequence of rapid urbanisation.

2 CONCEPTUAL SYNOPSIS

Henri Lefebvre's theory of the production of space argues that space is not simply a physical or natural entity but is produced through social, economic, and political processes. Lefebvre (2014) stated that space is a social product that reflects the dominant social relations, power structures, and cultural values of a particular society. Lefebvre contends that space is not neutral, but is shaped by historical processes of colonization, urbanization, and capitalist development. Schmid (2022) suggests that space is a complex and dynamic entity that is constantly being produced and reproduced through human activity and that it is not a fixed or static entity. Moreover, Lefebvre (2014) introduces the idea of "social space" which encompasses not only physical dimensions but also the social practices, power dynamics, and symbolic meanings that shape how space is used and understood (Delaisse *et al.* 2021). Lefebvre identifies three interconnected aspects of space production as indicated in Figure 1.

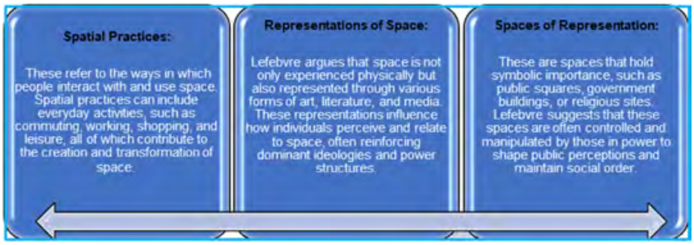

Figure 1. Three interconnected aspects of space production. Source: Author, 2023.

The production of space theory helps to understand the complex and dynamic processes that shape peri-urban areas such as Makhado Biaba town and the surrounding peri-urban villages. These areas are often subject to intense pressures from urbanization, population growth, and economic development, which can lead to significant changes in land use and spatial organization. These changes are not solely the result of natural or physical forces but are the product of social, economic, and political processes that reflect the dominant power relations and cultural values of society (Fuchs 2019). The key contribution of Lefebvre's theory to peri-urban areas is its emphasis on the role of power in shaping space. Jabareen and Eizenberg (2021) argue that space is not a neutral entity but is produced through power relations and social conflict. In peri-urban areas, power relations between different groups, such as developers, landowners, and local communities, can have a significant impact on land use decisions and spatial organization (Chirisa *et al.* 2022; Owusu Ansah and Chigbu 2020).

Lefebvre's theory highlights the importance of cultural values in shaping space. In the area of focus, cultural values can influence land use decisions and spatial organization (Griffiths and Vaughan 2020). For example, cultural values that prioritise agriculture or conservation may lead to land use decisions that protect open space or farmland. Conversely, cultural values that prioritize economic development may lead to land use decisions that prioritize industrial or residential development (Perrin and Nougaredes 2022). Lefebvre's theory shows how cultural values shape land use decisions and spatial organization in peri-urban areas. Consequently, the theory emphasizes the dynamic and complex nature of space. Lefebvre argues that space is not a fixed or static entity but is constantly being produced and reproduced through human activity (Brenner 2019). In the area of focus, this means that land use decisions and spatial organization are subject to change over time. The production of space theory draws attention to the importance of social relations in shaping space. Lefebvre (2014) argues that space is produced through social relations and that these relations can be characterized by conflict and struggle (Benade 2021). In the area of focus, this means that land use decisions and spatial organization are often the product of social conflict between different groups with different interests and values. The production of space theory helps to understand the social dynamics of peri-urban areas and the need for inclusive planning processes that take into account the diverse perspectives and interests of different groups. Finally, the production of space theory emphasizes the importance of everyday life in shaping space. Lefebvre (2014) argues that space is produced through the everyday practices of people and that these practices are often overlooked in traditional planning approaches (Farrington 2021). Therefore, in peri-urban areas, land use decisions and spatial organization are shaped by the everyday practices of residents and users of these areas. Lefebvre's theory of the production of space helps in understanding the importance of everyday practices in shaping spaces and the need for participatory planning approaches that engage with the experiences and perspectives of peri-urban communities in Makhado Biaba town.

3 METHODOLOGY

This study adopted a case study design. A mixed method approach was used to fully explore the research question: "What are the challenges faced by rural peri-urban areas as a consequence of rapid urbanisation" A case study design was chosen to extract insights on transformation and challenges of peri-urban expansion in small rural towns and surrounding communities. This work relied heavily on interviews and questionnaires. Key informant interviews were conducted with key informant personnel from Makhado local municipality. Interviews were conducted with 9 respondents, of which 4 of them were from the planning department and 5 were traditional leaders. 180 questionnaires were distributed to people who reside in Makhado Biaba and surrounding communities. Interviews with the municipal officials were unstructured and the interviews were conducted physically, and the questioners conducted with residents were structured. Random sampling was used to select households that were targeted for participating in the survey. literature was also used to support the information gathered using interviews and questionnaires. The data in this study was analysed statistically and thematically. Thematic analysis was used to present and examine the interview qualitative data. The Statistical Packages for Social Sciences (SPSS) version 25 and Stata 14 to run statistical analyses. Furthermore, a quantitative statistical method was used to analyse data and that is exploratory factor analysis.

4 FINDINGS AND DISCUSSIONS

Community members indicated that if they have burning issues as a community or if the chief wants to communicate with the community about anything affecting them directly or indirectly they call a community meeting "Khoroni". The community meetings emerge as a critical instrument in fostering development in the area as the local municipality governance structures seem to be less effective when it comes to the basic needs of the surrounding villages (peri-urban areas). The respondents indicated that the meetings allow individuals to voice their concerns, and bring together residents, other stakeholders and the chief to discuss, plan and implement strategies that may lead to improved quality of life and growth in the community. One of the community members indicated that the community meetings are uniquely positioned to address localised problems that have not been receiving adequate attention from the Makhado local municipality such as the water scarcity issue which has been there for decades. Residents in Tshituni (tsha fahasi) area gave an example of how some of the community members have formed a group where each person has to contribute money in order to have access to water, some community members managed to connect pipes from the mountain down to the community so that people who are paying monthly to stay connected however, not everyone can afford to pay for the water monthly. Community meetings are the epitome of grassroots democracy and local empowerment. Jian and Hou (2023), emphasises the essential role of urban social space in sustainable development. By highlighting that the social dimension often receives less attention compared to economic and environmental aspects in sustainable development discussions. However, the social aspects are crucial as they directly impact community well-being, social integration, and equitable access to urban resources.

4.1 *Impact of governance structures on peri-urban development*

Out of the sample of 5 traditional leaders who were interviewed about whether they were satisfied with the practice of land management in the study area, three (60%) of them were not satisfied with the land management practices in the area. These three traditional leaders gave various reasons as to why they were not satisfied as indicated in Table 1.

Table 1. Traditional leaders' views on land management and their "effect on the Community".

Dissatisfaction with land management in the study area by Traditional Leaders	Effect on the community
The planning department uses a top-down approach	May result in projects that do not align with the specific needs, preferences, and cultural values of the community
Issues of land ownership between chiefs and local municipality	Uncertainty regarding land tenure can make it difficult for businesses and developers to secure financing or invest in long-term projects which leads to limited job opportunities and slow economic growth, affecting the overall development of the community.
Municipality wanting to take the roles and responsibilities of traditional leaders	Improved infrastructure and service delivery to local communities since the municipality often has better access to resources and funding.

Source: Field Survey, 2022.

The conflict between traditional leaders and local government structures continues to be a major issue in South African local governance. It is worth noting that more than 60% of the total sample of traditional leaders had reasons not to be satisfied with land management in their areas. All the reasons for their dissatisfaction pointed at the local government as the cause. As indicated in Table 1, traditional leaders argued that the local municipality uses a top-down approach which is the issue of inappropriate communication channels being used by the local municipality. One of the traditional leaders indicated that the reason why most traditional leaders show weak involvement in matters of land management with the local municipalities is not because of lack of willingness but rather lack of understanding by local municipalities on the role and responsibilities of traditional leaders. This lack of appropriate communication affects poor working relations between local municipalities and traditional leaders. Although traditional leadership is often intended to address cultural and social issues, its importance in land use planning and management should be recognized. This argument stems from the fact that traditional leaders have accused local municipalities of manipulating them when they require community assistance, and they are rarely consulted. Spatial Planning and Land Use Management Act (SPLUMA) 16 of 2013 authorized by Section 81 of the Municipal Systems Act of 1998, allocated clearly functions given to traditional leaders with respect to municipal duties to work together for the development of their areas, yet the reality is different in most of the municipalities in South Africa including Makhado local municipality.

Municipalities have been involved in numerous land disputes with traditional leaders, an indication that governance and administration are tipping. As indicated in table 1, the issue of land ownership between chiefs and the local municipality was brought up by one of the traditional leaders who provided an incident that happened between the Netshituni traditional leadership and the Makhado local municipality. In this incident, a dispute erupted over a plot of land measuring approximately 100 hectares in the area. The Netshituni traditional leadership contended that because the land belonged to them, the municipality had no legal right to auction it. The municipality, on the other hand, had already begun the auction process since the land belongs to the municipality. However, the issue has been handed over to court and is being dealt with by the law.

4.2 *Assessment of 'peri-urban expansion'*

Figure 2 shows that of the total 180 participants, the largest share of 58% (n = 105) mentioned that peri-urban expansion did not affect their chances of accessing basic services, while 26% (n = 47) indicated that peri-urban expansion affected their chances of accessing basic services. Services play an important role in a territory's economic and social development.

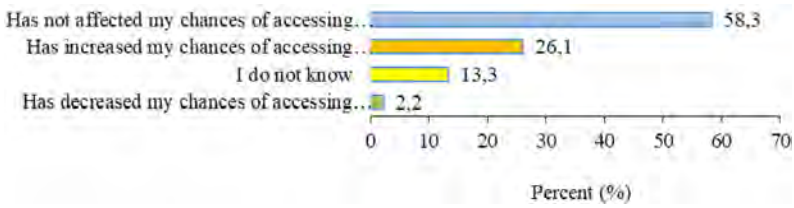

Figure 2. How has peri-urban expansion affected your chances of access to services. Source: Field Survey, 2022.

Figure 3 shows that of the total 180 participants, the largest share of 39% (n = 71) reported that the change in the spatial character of the area became more commercial, while 37% (n = 66) stated that change in the spatial character of the area did not change.

Figure 3. Change in the spatial character of the area. Source: Field Survey, 2022.

Figure 4 shows that of the total 180 participants, the largest share of 71% (n = 128) mentioned that the service most needed in their area is water provision, while 24% (n = 43) indicated that road infrastructure is most needed. Therefore, water provision and road infrastructure are the services most needed in their areas in Makhado Biaba peri-urban area, Makhado Local Municipality.

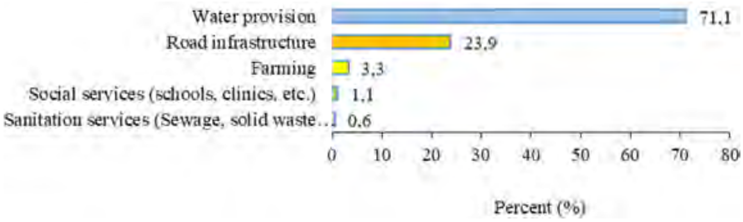

Figure 4. Services most needed in the area. Source: Field Survey, 2022.

4.3 *Exploratory factor analysis*

Exploratory factor analysis was performed to measure the construct validity of items assessing 'peri-urban expansion'. The statistics reported include sampling adequacy tests, total variances explained and the factor structure assessed based on sizes of items' loadings.

4.3.1 *Exploratory factor analysis*

The sampling adequacy of survey items was assessed using the Keiser-Meyer-Olkin (KMO) measure of sampling adequacy criterion by subjecting all the retained items to alpha factoring with the Keiser normalization procedure following Kaiser (1974). Statistical results on sampling adequacy of observed survey items are presented in Tables 2 and 3 below.

Table 2. Correlation matrix[a].

		How has peri-urban expansion affected your chances of access	Change in the spatial character of the area	Services most needed in the area
Correlation	How has peri-urban expansion affected your chances of access	1.000		
	Change in the spatial character of the area	.151	1.000	
	Services most needed in the area	−.209	−.120	1.000

a. Determinant = .927
Source: Author, 2023.

Table 2 shows the presence of a weak positive correlation between change in the spatial character of the area and how peri-urban expansion affected the chances of accessing services. On the other hand, 'services most needed in the area' had negative correlations with 'how peri-urban expansion affected chances of access services' and 'change in the spatial character of the area'.

Table 3 presents results on the sampling adequacy of items used to measure access to services. Such sampling adequacy was assessed using the Keiser-Meyer-Olkin (KMO)

Table 3. Sampling adequacy statistics.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.562
Bartlett's Test of Sphericity	Approx. Chi-Square	13.459
	df	3
	Sig.	.004

Source: Author, 2023.

measure of sampling adequacy criterion by subjecting all retained items to alpha factoring with the Keiser normalization procedure following Kaiser (1974). The computed overall KMO-MSA value equal to 0.562 is above the minimum acceptable 0.500 (Chan and Idris 2017), confirming the sampling adequacy of items used to assess *peri-urban expansion*. The Bartlett's test of sphericity chi-square statistic (13.459, p = 0.004) statistically significant at 1 percent level rejects the null hypothesis that the items' correlation matrix is equal to an identity matrix, indicating that the data diverges from an identity matrix, hence exploratory factory analysis was appropriate to be conducted.

4.3.2 *Total variances explained*

Following the measurement of sampling adequacy, total variances explained analysis through the alpha factoring extraction and Varimax rotation procedure was performed to evaluate the crucial patterns of observed indicators used in this research study. The total variances explained were extracted to measure smaller sets of latent variables or constructs underlying particular items observed to inform the evaluation of the validity of constructs. The alpha factoring extraction criterion was used to optimise the alpha validity of factors. Results of total variances explained of the peri-urban expansion construct are presented in Table 4 below.

Table 4. Total variances explained.

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.323	44.093	44.093	.514	17.120	**17.120**
2	.889	29.649	73.742			
3	.788	26.258	100.000			
Extraction Method: Alpha Factoring.						

Source: Author, 2023.

Table 4 presents the results of the total variances explained by indicators assessing '*peri-urban expansion*'. Based on extraction sums of squared loadings, the cumulative 17.1% total variance in the data was accounted for by one factor. Given that merely one factor was extracted in the solution of the final extraction iteration, there was no basis to perform the detection of a complex structure in the pattern of the dataset's factor loadings. Therefore, all items that loaded on the extracted single factor were retained for further analysis.

4.3.3 *Factor structure*

Factor loadings of observed items assessing the construct 'peri-urban expansion' are presented in Table 5. Loadings show correlations between observed items and their analogous factors. Thus, a factor loading is statistically a correlation coefficient that indicates the amount of variance explained by an observed item on its relevant factor. Following Awang (2012), factor loadings for newly developed items should exceed 0.5 for each item, while factor loadings for established items should exceed 0.6 for each item under each formulated construct.

Given that this research study used newly developed items, a factor loading threshold of at least 0.5 was, therefore used accordingly, and items with loadings less than 0.5 were eliminated from the analysis. Similarly, items that demonstrated a complex structure (items with a score of at least 0.5 that loaded on more than one factor) were removed from the analysis. Factor loading results for the items under each construct are presented in Table 5.

Table 5. Rotated factor matrix[a].

	Factor 1
C3.1. How has peri-urban expansion affected your chances of accessing services	0.509
C3.3. Services most needed in the area	−0.409
C3.2. Change in the spatial character of the area	0.296
Extraction Method: Alpha Factoring.	

a. 1 factors extracted. 9 iterations required.
Source: Author, 2023.

Table 5 factor matrix loadings of items measuring the construct 'peri-urban expansion' loaded on one factor, showing convergent validity. From the total three items, the only item that had the highest association (loading > = 0.5) with the construct 'peri-urban expansion' is the one on 'how peri-urban expansion affected participants' chances of access to services (loading = 0.509). The other two observed indicators had loadings lower than the required 0.5 minimum threshold.

5 LESSONS LEARNT, RECOMMENDATIONS AND CONCLUSION

The case of Makhado Local Municipality highlights the significance of collaboration between traditional leaders and municipal authorities in village peri-urban areas. Traditional leaders play a crucial role in cultural and social matters, as well as in land management, and their involvement is essential for sustainable development and promoting resilient communities. The dissatisfaction among traditional leaders regarding land management practices underscores the importance of effective communication channels between traditional leaders and local government structures. Lack of understanding and miscommunication can lead to conflicts and hinder development initiatives. The conflict between traditional leaders and local municipalities points to the need for clear legal frameworks governing land management, particularly in areas where customary law coexists with modern land use regulations. SPLUMA aims to address these issues, but its implementation requires better alignment with traditional leadership structures. Consequently, community meetings serve as vital platforms for addressing local issues and fostering grassroots democracy. They provide an avenue for community members to voice their concerns and actively participate in decision-making processes, especially when municipal governance structures fall short in addressing their needs. The study identified water provision as the most needed service in the area, followed by road infrastructure. Understanding these critical needs is vital for policymakers and planners to prioritize resource allocation and infrastructure development effectively.

To foster resilient and thriving communities in peri-urban areas both traditional leaders and municipal authorities should prioritize improving communication channels and understanding each other's roles and responsibilities. Regular dialogue and consultation can help build trust and facilitate collaborative decision-making. Efforts should be made to reconcile traditional governance systems with modern legal frameworks, such as SPLUMA, to ensure coherence and minimize conflicts over land management. This may involve revisiting legislation and engaging traditional leaders in the policymaking process. Training programs and capacity-building initiatives should be implemented to enhance the understanding of traditional leaders and municipal officials regarding land management practices, legal frameworks, and their respective roles. This can promote effective cooperation and accountability. Municipalities should prioritize community engagement and empowerment initiatives, such as community meetings, to ensure that local voices are heard and incorporated into decision-making processes. This can help address local needs and promote inclusive development. Given the critical need for water provision and road infrastructure identified in the study, policymakers and local authorities should prioritize investment in these areas to support the growing peri-urban population. This could involve infrastructure development projects and improved service delivery mechanisms.

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Road network analysis of connectivity and accessibility indices in Blantyre, Malawi

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ABSTRACT: Road network analysis is critical in the development of urban areas as road networks play a significant role in urban economy. This therefore necessitates the need to analyse road networks and their performance to ensure sustainability in the road infrastructure and development at large. In this paper connectivity and accessibility indices were measured within the study area over the past 25 years. Connectivity indices indicated significant changes with the gamma index changing from 43.7% in 1998 to 47.6% in 2023. The beta index increased from 1.26 to 1.36 in the 25-year period. The alpha index made a significant increase from 14.6% in 1998 to 20.5% in 2023. The accessibility indices also made some significant changes with the Shimbel index moving from 95 in 1998 to 85 for the most accessible location. The study offers significant insights into the evolution of Blantyre's urban infrastructure, providing foundation for future planning and development.

Keywords: Road network, Sustainability, Connectivity, Accessibility, Infrastructure

1 INTRODUCTION

Urbanization is a key driver of economic development, particularly in developing countries such as Malawi (Shi *et al.* 2019). As cities expand, the demand for efficient transport systems becomes critical to facilitate the smooth movement of people and goods, directly impacting economic activities and quality of life (Khasieva 2021). In developing countries, urban areas often struggle with inadequate infrastructure, limited funding, and rapid population growth. This often leads to negative impacts on the transport system such as increased congestion, leading to traffic accidents and delays thereby affecting economic activities (Thondoo *et al.* 2020). This also has great impact on the environment as increased vehicle ownership and congestion increase air pollution and noise pollution in the urban area (Thondoo *et al.* 2020). These challenges highlight the necessity of innovative strategies and technologies to improve urban transport systems (Kumar and Kumar 2016). Improved road networks can significantly enhance accessibility, making urban areas more attractive for commercial development and increasing economic activities (Dagnachew 2007; Kone 2018). This therefore necessitates comprehensive transport network analysis to properly understand the performance of the road network which will guide sustainable infrastructure planning.

Malawi is a landlocked country located in the southern region of Africa. Its transportation system relies on roads and railways to manage the movement of goods and people. According to data provided by the Roads Authority (RA) in Malawi, roads are responsible for handling and supporting 70% of internal freight and 99% of passenger traffic. This makes the road network system the main transport system used in Malawi (Ministry of Transport and Public Works 2017). Malawi possesses a road network spanning 15,451 km which is classified into main roads (21.7%), Secondary roads (20.2%), Tertiary roads (26.7%), District roads (22.7%), and Urban roads covering 8.7% of the total road network (Ministry of

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Transport and Public Works 2017). Of this network, 4,038 kilometers are paved roads, accounting for 26% of the overall road network in the country (Emuze and Kadangwe 2014). Due to economic constraints, the allocation of financial resources to the road sector has not been sufficient to meet the maintenance requirements. As a result, the service delivery for road infrastructure construction and management has significantly declined since the 1990s (Emuze and Kadangwe 2014).

Transportation systems are often conceptualized as networks to illustrate their flows and structures. A network comprises interconnected pathways among designated points, or nodes, which can represent towns or intersections. The connections between these nodes, known as edges or linkages, include physical routes like roads and railways as well as more abstract routes such as air and sea corridors. Networks can be static, representing a snapshot in time, or dynamic, evolving with changes over time (Frank *et al.* 2008). By focusing on the nodes and linkages, transportation networks can be transformed into topological graphs that represent spatial arrangements without considering physical distances (Abbas and Hashidu 2019). This conceptual framework is crucial for understanding and analysing transportation networks, as it highlights the interconnectedness and structural patterns within the system.

The utilization of Remote Sensing and Geographical Information System (GIS) technology may greatly enhance the planning, analysis, and decision support system operations, thereby significantly impacting the development and growth of urban areas. In order to effectively tackle urban difficulties, it is crucial to devise new techniques that make use of inductive problem-solving methodologies. These techniques should be capable of accommodating the ever-changing demands of urbanization. For instance, when the spatial entity is linked to non-spatial features, it can be beneficial for achieving sustainable infrastructure planning or strategy. Therefore, applying GIS technology as a tool in assisting transport network research or planning is greatly influenced by this crucial feature. In the GIS platform, the transport network database is typically expanded by integrating attribute and spatial data (Ajay and Bharti 2013).

This study aims to analyse the performance of the transport system by measuring the connectivity and accessibility indices over a 25-year period, from 1998 to 2023. The ArcGIS software was used for digitalizing the road network from Google Earth image archives of 1998 and 2023. Specific points of various land uses were selected for analysis as nodes. This study is the first ever to be done in Malawi and seeks to contribute to the understanding of how transport network improvements can support sustainable urban growth in developing countries. By analysing the changes in Blantyre's road network from 1998 to 2023, the research provides insights into the effectiveness of past infrastructure investments and identifies areas needing further improvement. The findings will offer valuable recommendations for policymakers and urban planners, emphasizing the need for strategic planning and investment in transport infrastructure to foster economic development and improve urban living conditions.

2 MATERIALS AND METHODS

2.1 *Geospatial data*

Google Earth satellite imageries were used to obtain road network data for the years 1998 and 2023 through digitalization in ArcGIS software. Satellite imageries were georeferenced and the road network shapefile was generated. Further, the points of interest such as healthcare facilities, educational institutions, recreational, residential areas, and shopping malls were also obtained from Google Earth images and shapefiles generated by ArcGIS software. Table 1 below shows the selected location points.

Table 1. Location points of different land use.

Point Location	Symbol	Point Location	Symbol
Ndirande residential area	A	Kachere slum	J
Chichiri Shopping Mall (Shoprite)	B	Hillview International School	K
Queen Elizabeth Hospital	C	Bangwe Secondary School	L
University 1 (MUBAS)	D	Chigumula residential area	M
Chilomoni residential area	E	Dr Sam Clinic	N
Chirimba Market	F	Limbe Market	O
Mbayeni residential area	G	Zingwangwa residential area	P
Maranatha Secondary School	H	Nancholi Market	Q
Zomba Road Country Lodge	I	Mwaiwathu Hospital	R
		Bangwe residential area	S

2.2 *Data processing*

Before converting the road network into a network data set to be used in network analysis, the digitalized road network was topologically corrected. This is important to remove all the errors made during digitalization. These network data sets were created from the line and point features. The count of edges (links) and nodes (nodes) in Table 2 were obtained from the network data set which were then used to calculate the connectivity indices.

Table 2. Edges and node count for road networks.

Year	No. Links (Edges)	No. Nodes (Vertices)
1998	59	47
2023	60	44

2.3 *Connectivity analysis*

Various indices have been developed describing the extent to which a network approaches maximum connectivity, which requires the existence of a direct link between each node (Kansky 1963). These indices are all based upon the relationship between the number of edges and vertices in a network which is regarded as a topological graph. The Beta Index, the Gamma Index, and the Alpha Index will be used in this study as these indices allow for the comparison of network connectivity for different periods.

Equation 1: Beta Index

$$\beta = e/V \tag{1}$$

Equation 2: Gamma Index

$$\gamma = e/(3(v - 2)) \times 100/1 \tag{2}$$

Equation 3: Alpha Index

$$\alpha = (e - v + 1)/(2v - 5) \times 100 \tag{3}$$

The Beta Index quantifies the ratio of edges (e) to vertices (v), representing the average number of connections per node. When considering the average of each period, the one with the highest value suggests the most connectivity, while the one with the least value shows the least connection (Abbas and Hashidu 2019).

The Gamma Index on the other hand is a measure of the ratio between the actual number of edges in a network and the greatest number of edges that could exist between a particular number of vertices. The denominator in the expression represents the inherent relationship between the insertion of a single vertex and the resulting rise in the number of potential edges by 3. When comparing different periods, the network with the highest % represents the era with the greatest level of connectivity, while the network with the lowest percentage shows the least connected period (Abbas and Hashidu 2019).

The Alpha Index is the ratio that considers the number of circuits in a network, rather than the number of edges. The alpha index is strongly correlated with the gamma index. A circuit is a closed path in a network that starts and finishes at the same node, without traversing any edge more than once. This indicates that when a traveller encounters a network with $\alpha=0$, they are only able to travel along one path even if there are multiple possibilities available. Conversely, in the case of a network with $\alpha=1$, there are several options for the traveller to choose from. Consequently, the time period with the strongest connectivity corresponds to the one with the highest ratio or percentage (Abbas and Hashidu 2019).

2.4 *Accessibility analysis*

After obtaining the different point locations for different land uses, the shortest distance matrix and shortest path matrix were formulated with the help of the network analyst tool in the ArcGIS software. In this study, both the Shimbel distance matrix and the shortest path matrix were used to measure accessibility (Tables 6, 7, 8 and 9). For the shortest path matrix, the associated number and Shimbel index were used to measure accessibility for each period. The associated number represents the number of arcs needed to connect one location to the most distant node or location (Abbas and Hashidu 2019). It is the highest number in the row for each point. The row with the smallest associated number is the most accessible while that with the highest value is the least accessible. The Shimbel index on the other hand represents the total number of arcs needed to connect one node or location to every other node in the network of the shortest distances in each row (Daniel *et al.* 2020). The Shimbel distance matrix on the other hand has the shortest distances or paths between locations and the total in every row is the Shimbel distance for that particular location point. A high value shows that the location is not easily accessible while a low value indicates that the location point is more accessible. The value of the Shimbel distance can be expressed as shown below:

Equation 4: Shimbel distance

$$S_i = \sum d_{ij} \tag{4}$$

Si is the Shimbel distance at location i, and dij represents the distance between the locations or nodes i and j.

3 RESULTS AND DISCUSSIONS

3.1 *Connectivity analysis*

Table 3 below gives a summary of the values of connectivity indices in the years 1998 and 2023 of the road network.

Table 3. Connectivity indices for 1998 and 2023.

Connectivity Indices	1998	2023
Gamma Index	43.7%	47.6%
Betta Index	1.26	1.36
Alpha Index	14.6%	20.5%

The Beta (β) Index simply measures the ratio of the number of edges (roads) to the number of vertices (intersections or nodes) in the transport network. A value of 1.26 in 1998 means that, on average, there were 1.26 roads per intersection while a value of 1.36 in 2023 indicates an average of 1.36 roads per intersection. This suggests that connectivity has improved over the period, as an increase in the number of roads typically means better accessibility and multiple routes between points. As the Alpha Index (α) measures the ratio of the number of actual circuits to the maximum possible number of circuits in the network, a value of 14.6% (or 0.146) in 1998 indicates that the network had 14.6% of the maximum possible circuits it could have. In 2023 a value of 20.5% (or 0.205) shows an increase in the proportion of actual circuits to the maximum possible, which implies that the network has become more connected and there are more alternative routes. This increase in the value of the Alpha Index reflects improved redundancy in the network, with more circuits providing multiple alternative paths, enhancing robustness and flexibility in the road network. The Gamma Index (γ) measures the ratio of the actual number of edges to the maximum possible number of edges in the network. Therefore, a value of 43.7% (or 0.437) in 1998 indicates that the network had 43.7% of the maximum possible edges it could have whilst a value of 47.6% (or 0.476) in 2023 indicates that the network had 47.6% of the maximum possible edges. This means more direct routes between points, reducing travel distance and time, and indicating overall improvement in network efficiency.

3.2 *Accessibility analysis*

The Shimbel distance measures the total distance from a node to all other nodes in the network, indicating its accessibility. In the year 1998, the most accessible node had a Shimbel distance of 112.01 km, while the least accessible node had a Shimbel distance of 286.94 km. In 2023, the most accessible node had a slightly increased Shimbel distance of 112.32 km, indicating a small increase in distance but overall similar accessibility. The least accessible node in 2023 had a decreased Shimbel distance of 266.38 km, indicating improved accessibility for the previously less accessible parts of the road network. The Associated Number (AN) measures the number of edges connected to a node, thereby, reflecting its degree of connectivity. In 1998, the most accessible node was connected to 9 other nodes, while the least accessible node was connected to 14 nodes. In the year 2023, the most accessible node was connected to 8 nodes, a slight decrease in direct connections. The least accessible node remained connected to 14 nodes in both years, indicating no change in its direct connectivity but potentially benefiting from overall network improvements. The Shimbel Index (SH) simply quantifies the relative accessibility of nodes, with lower values indicating higher accessibility. In 1998, the most accessible node had an SH of 95, and the least accessible had an SH of 196. In 2023, the most accessible node had an SH of 85, showing improved accessibility for the most accessible node. The least accessible node had an SH of 154 in 2023, indicating a significant improvement in accessibility for the least accessible nodes compared to 1998. These changes suggest that the road network has become more balanced and accessible over the 25 years, particularly improving conditions for previously less accessible areas. This indicates a more equitable distribution of accessibility across the network. Table 4 below gives a summary of what is comprised in Tables 6, 7, 8 and 9.

Table 4. Accessibility indices comparison.

Accessibility indices	Most accessible 1998	Least Accessible 1998	Most accessible 2023	Least Accessible 2023
Shimbel distance (km)	112.01	286.94	112.32	266.38
Associated number (AN)	9	14	8	14
Shimbel Index (SH)	95	196	85	154

From the shortest path matrix, it can also be observed that for the year 1998, only 8 locations were below the Shimbel index value of 125 while 9 of the locations had Shimbel index values between 125 and 155, leaving only two locations having a value greater than 155. The values obtained in 2023 showed changes in the accessibility of the road network with 13 locations having values of Shimbel index below 125 and the rest of the 6 locations having values ranging between 125 to 155. Table 5 gives a summary of the Shimbel index values.

Table 5. Summary of Shimbel index values.

Shimbel Index Range	Number of Locations (1998)	Number of Locations (2023)
Below 125	8	13
125 - 155	9	6
Above 155	2	0

Table 6. Short path matrix of the road network of Blantyre in 1998.

1998	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	AN	SH
A	0	3	3	3	5	2	5	5	7	6	8	9	8	6	5	7	7	3	6	9	107
B	3	0	1	1	4	5	4	4	6	5	7	8	7	9	4	5	5	4	5	9	96
C	3	1	0	1	4	5	4	4	6	5	7	8	7	9	4	5	5	3	5	9	95
D	3	1	1	0	4	5	4	4	6	5	7	8	7	9	4	5	5	3	5	9	95
E	5	4	4	4	0	5	1	4	9	8	10	11	10	11	7	7	4	3	8	11	126
F	2	5	5	5	5	0	3	3	9	8	10	11	10	12	7	8	7	3	8	12	133
G	5	4	4	4	1	3	0	4	9	8	10	11	10	11	7	7	4	3	8	11	124
H	5	4	4	4	4	3	4	0	4	3	6	5	6	12	5	8	8	5	3	12	105
I	7	6	6	6	9	9	9	4	0	2	8	5	8	14	7	14	10	8	2	14	148
J	6	5	5	5	8	8	8	3	2	0	7	4	7	13	6	13	9	7	1	13	130
K	8	7	7	7	10	10	10	6	8	7	0	3	1	10	4	10	12	9	7	12	148
L	9	8	8	8	11	11	11	5	5	4	3	0	3	11	5	11	13	10	4	13	153
M	8	7	7	7	10	10	10	6	8	7	1	3	0	10	4	10	12	9	7	12	148
N	6	9	9	9	11	12	11	12	14	13	10	11	10	0	8	6	8	10	13	14	196
O	5	4	4	4	7	7	7	5	7	6	4	5	4	8	0	8	10	6	6	10	117
P	7	5	5	5	7	8	7	8	14	13	10	11	10	6	8	0	3	6	13	14	160
Q	7	5	5	5	4	7	4	8	10	9	12	13	12	8	10	3	0	5	9	13	149
R	3	4	3	3	3	3	3	5	8	7	9	10	9	10	6	6	5	0	7	10	114
S	6	5	5	5	8	8	8	3	2	1	7	4	7	13	6	13	9	7	0	13	130

3.3 *Discussion*

From the obtained results it can therefore be concluded that over the past 25 years, there has been significant improvement in connectivity and accessibility of the road network in Blantyre. The increase in the Beta Index reflects a denser network with more roads per intersection. The increase in the value of the Alpha Index indicates a higher proportion of circuits, enhancing redundancy and flexibility. The growth in the Gamma Index shows that a greater proportion of possible connections have been realized, improving the overall efficiency and connectivity of the road network. This combined increase in all indices suggests that the road network in 2023 is more robust, accessible, and efficient compared to 1998.

A Shimbel index below 125 indicates higher accessibility meaning a lower total distance is needed to all other nodes in the network. The increase in the number of locations from 8 to 13 locations with indices below 125 suggests a significant improvement in accessibility for these locations. This means that in 2023 more areas became easier to reach within the

Table 7. Short path matrix of the road network of Blantyre in 2023.

2023	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	AN	SH
A	0	3	3	3	5	2	5	5	7	6	8	9	8	10	5	7	7	3	6	10	102
B	3	0	1	1	4	5	4	4	6	5	7	8	7	8	4	5	5	4	5	8	86
C	3	1	0	1	4	5	4	4	6	5	7	8	7	8	4	5	5	3	5	8	85
D	3	1	1	0	4	5	4	4	6	5	7	8	7	8	4	5	5	3	5	8	85
E	5	4	4	4	0	5	1	4	6	8	10	11	10	10	7	7	4	3	8	11	111
F	2	5	5	5	5	0	3	3	5	8	10	11	10	11	7	8	7	3	8	11	116
G	5	4	4	4	1	3	0	4	6	8	10	11	10	10	7	7	4	3	8	11	109
H	5	4	4	4	4	3	4	0	4	3	6	5	6	10	5	12	8	5	3	12	95
I	7	6	6	6	6	5	6	4	0	2	8	5	8	11	7	14	10	8	2	14	121
J	6	5	5	5	8	8	8	3	2	0	7	4	7	10	6	13	9	7	1	13	114
K	8	7	7	7	10	10	10	6	8	7	0	3	1	7	4	10	12	9	7	12	133
L	9	8	8	8	11	11	11	5	5	4	3	0	3	8	5	11	13	10	4	13	137
M	8	7	7	7	10	10	10	6	8	7	1	3	0	7	4	10	12	9	7	12	133
N	10	8	8	8	10	11	10	10	11	10	7	8	7	0	5	5	7	9	10	11	154
O	5	4	4	4	7	7	7	5	7	6	4	5	4	5	0	8	10	6	6	10	104
P	7	5	5	5	7	8	7	12	14	13	10	11	10	5	8	0	3	6	13	14	149
Q	7	5	5	5	4	7	4	8	10	9	12	13	12	7	10	3	0	5	9	13	135
R	3	4	3	3	3	3	3	5	8	7	9	10	9	9	6	6	5	0	7	10	103
S	6	5	5	5	8	8	8	3	2	1	7	4	7	10	6	13	9	7	0	13	114

Table 8. Transition Matrix (2008-2018).

1998	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Shimbel distance
A	0.00	3.11	4.46	3.93	5.99	5.68	6.66	13.96	16.67	9.23	9.54	12.04	11.43	10.66	6.87	8.45	8.45	2.96	8.36	148.46
B	3.11	0.00	1.35	0.82	5.67	7.08	6.34	11.10	13.80	6.37	6.67	9.17	8.56	7.54	4.00	5.34	6.03	3.55	5.49	112.01
C	4.46	1.35	0.00	0.53	4.32	7.15	4.99	12.45	15.15	7.71	8.02	10.52	9.91	6.20	5.35	3.99	4.68	2.27	6.84	115.89
D	3.93	0.82	0.53	0.00	4.85	7.68	5.52	11.92	14.63	7.19	7.49	9.99	9.38	6.72	4.82	4.52	5.21	2.80	6.31	114.31
E	5.99	5.67	4.32	4.85	0.00	7.91	0.67	15.07	19.47	12.03	12.34	14.84	14.23	9.96	9.67	7.76	7.24	3.03	11.16	166.19
F	5.68	7.08	7.15	7.68	7.91	0.00	8.12	9.18	20.64	13.20	13.51	16.00	15.40	12.79	10.83	10.59	10.36	4.88	12.32	193.32
G	6.66	6.34	4.99	5.52	0.67	8.12	0.00	14.40	20.14	12.70	13.01	15.51	14.90	10.63	10.34	8.43	7.91	3.70	11.83	175.79
H	13.96	11.10	12.45	11.92	15.07	9.18	14.40	0.00	17.74	10.30	11.88	14.00	13.77	16.25	9.37	16.44	17.13	14.06	9.42	238.44
I	16.67	13.80	15.15	14.63	19.47	20.64	20.14	17.74	0.00	7.44	14.30	16.00	16.19	18.67	11.79	19.04	19.84	17.11	8.32	286.94
J	9.23	6.37	7.71	7.19	12.03	13.20	12.70	10.30	7.44	0.00	6.86	8.57	8.75	11.23	4.35	11.61	12.40	9.67	0.88	160.49
K	9.54	6.67	8.02	7.49	12.34	13.51	13.01	11.88	14.30	6.86	0.00	5.67	1.89	9.13	2.68	9.50	11.84	9.98	5.98	160.29
L	12.04	9.17	10.52	9.99	14.84	16.00	15.51	14.00	16.00	8.57	5.67	0.00	7.56	11.62	5.18	11.99	14.34	12.48	7.69	203.16
M	11.43	8.56	9.91	9.38	14.23	15.40	14.90	13.77	16.19	8.75	1.89	7.56	0.00	11.02	4.58	11.39	13.73	11.87	7.87	192.43
N	10.66	7.54	6.20	6.72	9.96	12.79	10.63	16.25	18.67	11.23	9.13	11.62	11.02	0.00	6.89	4.01	6.35	7.92	10.36	177.96
O	6.87	4.00	5.35	4.82	9.67	10.83	10.34	9.37	11.79	4.35	2.68	5.18	4.58	6.89	0.00	7.26	9.60	7.31	3.47	124.34
P	8.45	5.34	3.99	4.52	7.76	10.59	8.43	16.44	19.04	11.61	9.50	11.99	11.39	4.01	7.26	0.00	2.34	5.71	10.73	159.10
Q	8.45	6.03	4.68	5.21	7.24	10.36	7.91	17.13	19.84	12.40	11.84	14.34	13.73	6.35	9.60	2.34	0.00	5.48	11.52	174.46
R	2.96	3.55	2.27	2.80	3.03	4.88	3.70	14.06	17.11	9.67	9.98	12.48	11.87	7.92	7.31	5.71	5.48	0.00	8.80	133.58
S	8.36	5.49	6.84	6.31	11.16	12.32	11.83	9.42	8.32	0.88	5.98	7.69	7.87	10.36	3.47	10.73	11.52	8.80	0.00	147.33

network, reflecting a more efficient and well-connected road system. On the other hand, a decrease in the number of locations within the middle range (125-155 SH) indicates a shift towards better accessibility. Some of the locations that previously had moderate accessibility (indices between 125 and 155) had improved to the point where their indices are now below 125, as we see an increase in that range from 8 locations to 13 locations. Locations with Shimbel indices above 155 are considered to have poor accessibility as they have a higher total distance to all other nodes or locations. The fact that no locations in 2023 fall into this category indicates that the network improvements have significantly enhanced accessibility across all areas, even the ones that were previously the least accessible.

Table 9. Shimbel distance matrix for 2023 road network.

2023	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Shimbel distance
A	0.00	3.11	4.46	3.93	5.99	5.68	6.66	13.96	16.67	9.23	9.54	12.03	11.43	10.99	6.87	8.45	8.44	2.96	8.35	148.77
B	3.11	0.00	1.35	0.82	5.67	7.08	6.34	11.10	13.80	6.37	6.67	9.17	8.56	7.88	4.00	5.34	6.03	3.55	5.49	112.32
C	4.46	1.35	0.00	0.53	4.32	7.15	4.99	12.44	15.15	7.71	8.02	10.52	9.91	6.53	5.35	3.99	4.68	2.27	6.84	116.20
D	3.93	0.82	0.53	0.00	4.84	7.67	5.51	11.92	14.62	7.19	7.49	9.99	9.38	7.06	4.82	4.52	5.21	2.80	6.31	114.62
E	5.99	5.67	4.32	4.84	0.00	7.91	0.67	15.07	19.41	12.03	12.34	14.83	14.23	10.29	9.67	7.76	7.24	3.03	11.15	166.44
F	5.68	7.08	7.15	7.67	7.91	0.00	8.12	9.18	13.52	13.20	13.50	16.00	15.39	13.12	10.83	10.59	10.36	4.88	12.32	186.50
G	6.66	6.34	4.99	5.51	0.67	8.12	0.00	14.40	18.74	12.70	13.01	15.50	14.90	10.96	10.34	8.43	7.91	3.70	11.82	174.69
H	13.96	11.10	12.44	11.92	15.07	9.18	14.40	0.00	8.80	10.30	11.88	14.00	13.77	14.39	9.37	15.49	17.13	14.05	9.42	226.65
I	16.67	13.80	15.15	14.62	19.41	13.52	18.74	8.80	0.00	7.44	14.29	16.00	16.18	16.81	11.78	17.90	19.83	17.11	8.31	266.38
J	9.23	6.37	7.71	7.19	12.03	13.20	12.70	10.30	7.44	0.00	6.86	8.56	8.75	9.37	4.35	10.47	12.40	9.67	0.88	157.45
K	9.54	6.67	8.02	7.49	12.34	13.50	13.01	11.88	14.29	6.86	0.00	5.67	1.89	7.26	2.68	8.36	10.70	9.98	5.98	156.12
L	12.03	9.17	10.52	9.99	14.83	16.00	15.50	14.00	16.00	8.56	5.67	0.00	7.56	9.76	5.18	10.85	13.19	12.47	7.69	198.98
M	11.43	8.56	9.91	9.38	14.23	15.39	14.90	13.77	16.18	8.75	1.89	7.56	0.00	9.15	4.57	10.25	12.59	11.87	7.87	188.25
N	10.99	7.88	6.53	7.06	10.29	13.12	10.96	14.39	16.81	9.37	7.26	9.76	9.15	0.00	5.02	4.34	6.68	8.25	8.49	166.37
O	6.87	4.00	5.35	4.82	9.67	10.83	10.34	9.37	11.78	4.35	2.68	5.18	4.57	5.02	0.00	6.12	8.46	7.31	3.47	120.18
P	8.45	5.34	3.99	4.52	7.76	10.59	8.43	15.49	17.90	10.47	8.36	10.85	10.25	4.34	6.12	0.00	2.34	5.71	9.59	150.49
Q	8.44	6.03	4.68	5.21	7.24	10.36	7.91	17.13	19.83	12.40	10.70	13.19	12.59	6.68	8.46	2.34	0.00	5.48	11.52	170.21
R	2.96	3.55	2.27	2.80	3.03	4.88	3.70	14.05	17.11	9.67	9.98	12.47	11.87	8.25	7.31	5.71	5.48	0.00	8.79	133.88
S	8.35	5.49	6.84	6.31	11.15	12.32	11.82	9.42	8.31	0.88	5.98	7.69	7.87	8.49	3.47	9.59	11.52	8.79	0.00	144.30

These improvements can be attributed to the development and expansion of the road network within the city, which involved the construction of new roads, enhancements to existing roads, and better traffic management, resulting in a more efficient and effective transportation system. The increase in road infrastructure is due to the increased land use developments. As the population within the urban area increases, there is a greater demand for socio-economic activities which leads to an increase in land use developments such as residential, commercial building, and industrial (Dagnachew 2007). These developments attract road development in the specific areas, thereby improving road connectivity and accessibility. However, in most developing countries these do not often keep up with the growing demand and result in transportation system problems such as congestion, and traffic accidents which lead to various environmental issues such as air and noise pollution (Shi *et al.* 2019).

4 LIMITATIONS

In this study, only the major and minor arterial roads were considered for connectivity and accessibility network analysis.

5 CONCLUSION

This study has provided a detailed analysis of the changes in Blantyre's transport network over a 25-year period, focusing on connectivity and accessibility indices from 1998 to 2023. The connectivity indices measured were the gamma, alpha, and beta indices. Accessibility was measured by generating the Shimbel distance matrix and the short path matrix which were then used to calculate the accessibility indices such as the Shimbel distance, associated number, and Shimbel index. The study employed ArcGIS software to digitize road networks from Google Earth image archives and analyse the various land use points as nodes. The study offers significant insights into the evolution of Blantyre's urban infrastructure.

The findings indicate great improvements in the connectivity and accessibility of the road network. These advancements can largely be attributed to the development and expansion of the road network, which involved constructing new roads, enhancing existing ones, and implementing better traffic management strategies. The growth in road infrastructure has been driven by increased land use development, as rising urban populations demand more residential, commercial, and industrial spaces. This has, in turn, attracted road development in specific areas, enhancing connectivity and accessibility. Over the past years the urban population in Blantyre has rapidly increased as recorded by the national statistical office (National Statistical Office, 2019).

In conclusion, while Blantyre's road network has seen marked improvements in connectivity and accessibility over the past 25 years, there is a pressing need for continued investment in and planning for urban transport infrastructure. This is because rapid urban population growth which often corresponds to an increase in vehicle ownership poses significant challenges. The pace of infrastructure development does not keep up with the growing transportation needs and this has led to ongoing issues such as congestion, traffic accidents, and environmental problems like air and noise pollution. These challenges emphasise the need for strategic urban planning that incorporates sustainable transportation solutions to accommodate the increasing population and vehicular traffic. Policymakers and urban planners must focus on creating a sustainable and efficient transportation system that can support the city's economic development and improve the quality of life for its residents. This includes not only expanding the road network but also integrating innovative technologies and strategies to manage the challenges posed by rapid urbanization. The insights gained from this study provide a valuable foundation for future infrastructure planning and development in Blantyre and similar urban areas in developing countries.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Assessing the Building Information Modeling (BIM) maturity of modular construction companies in Sub-Saharan Africa

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ABSTRACT: Maximizing benefits from Building Information Modeling on any project depends on the level at which BIM is deployed, reflecting the BIM maturity of project stakeholders. This research assesses the BIM maturity levels of modular construction companies in Sub-Saharan Africa to better understand the current landscape and offer valuable insights that can enhance the integration of BIM in modular construction within the region. A descriptive research design was adopted, involving the collection of quantitative data from modular construction companies selected purposively across Sub-Saharan African countries. The collected data were analyzed using descriptive techniques to make informed conclusions. The study reveals that Sub-Saharan African modular construction companies are in the early BIM Maturity stages (1 and 2). Limited use of collaborative platforms indicates growth opportunities. Recommendations include investing in technological infrastructure and adopting BIM early in project planning.

Keywords: Building Information Modeling, BIM maturity, modular (offsite) construction, Sub-Saharan Africa, technological infrastructure

1 INTRODUCTION

Building Information Modeling (BIM) and Modular (offsite) construction are two innovative approaches that can help the construction industry in many ways to overcome its current challenges (Abanda *et al.* 2017; Yin *et al.* 2019). The two technologies are highly interrelated and can be applied together to ensure the maximization of profits in the construction industry (Sabet and Chong 2020; Yin *et al.* 2019).

Modular construction refers to factory-built building units completely fabricated in a manufacturing plant away from the site and then transported and assembled on-site (Pasquire and Connolly 2002). A modular building typically includes multiple three-dimensional rooms with fully installed mechanical, electrical, and plumbing components (Lee *et al.* 2020; Pasquire and Connolly 2002). According to Ferrer (2019), modular construction comprises four main stages; design and planning, factory manufacturing, transportation of units to the site, and on-site assembly.

One noteworthy aspect of modular construction is the concurrency of various stages, allowing onsite work while modules are being assembled in a factory (Wuni and Shen 2019). This, especially in larger-scale projects, is essential for productivity and efficiency. In addition, modular units are transported and finally placed while others are still in the assembly line, requiring extensive planning and coordination (Robey and Issa 2015). This concurrent execution strategy significantly shortens the construction timeline, facilitating earlier building occupancy (Wuni and Shen 2020a).

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Common benefits over traditional construction on-site include improved quality, good health and safety, better working conditions, higher tolerances, lower costs and reduced labor re-works, lower construction waste, simplified construction processes, products that are factory tried and tested, predictable sustainability performance, better control and consistency in products and processes (Arowoiya and Oyefusi 2023; Bello *et al.* 2023; Ferrer 2019; Ghannad *et al.* 2020; Idris and Adamu 2022; Razkenari *et al.* 2020; Wuni and Shen 2019b).

Despite these immense benefits, extensive demand for pre-project planning and coordination among members of cross-interdisciplinary professionals has significantly impeded the application of this technique (Lu and Korman 2010). According to some researchers, the total time from design to onsite assembly may exceed that of traditional construction if not optimally used (Banihashemi *et al.* 2018; Liu *et al.* 2018; Wang *et al*. 2020). These challenges must be addressed to optimize the benefits of modular construction.

The integration of BIM has been identified as a potential solution to improve collaboration and efficiency in modular construction by providing the required information in the appropriate format at the correct time and location (Li *et al*. 2019). As a result, there has been a growing number of studies on this topic in recent years, such as the benefits and barriers of BIM in modular construction (Ang *et al*. 2021; Mahmoud *et al*. 2022; Mostafa *et al*. 2018; Tan *et al*. 2019; Wu *et al*. 2021; Xu *et al*. 2023) and framework for BIM implementation in modular construction (Li *et al.* 2019; Samarasinghe *et al.* 2015; Wa *et al.* 2019).

BIM contains life-cycle data about the building information that can support various tasks such as design reviews, constructability reviews, and process and construction cost simulations through the digital visualization of target buildings based on 3D modeling (Sacks *et al.* 2018). Moreover, it is capable of producing architectural drawings and detailed sections of all components of prefabricated structures (Robey and Issa 2015; Wang *et al*. 2020). BIM-based software can create a visual model using standard component creation and Design for Manufacture and Assembly (DfMA). This is useful for the stakeholders in making logical and up-to-date decisions about changes in design and prefabricated module production over the project life cycle (Wasim *et al.* 2020).

In addition, the object-oriented attributes of BIM can be combined with the production-oriented characteristics of modular construction to improve efficiency and decision-making in modular construction, which would further enhance stakeholder collaboration (Li *et al*. 2019). Similarly, BIM improves virtual construction, supports decision-making, enhances marketing, reduces lead time, and removes design errors (Lee 2019; Ramaji *et al.* 2014). It also provides a platform for fabricators to easily manage information and improve internal processes by supporting parametric and customized parts and relationships and importing product model information from designers' BIM platforms (Chong *et al*. 2021; Zhai *et al.* 2019).

However, optimizing the benefits of Building Information Modeling (BIM) on any project depends on the level at which BIM is deployed. This is a function of the BIM Maturity Levels of the various BIM Operators and stakeholders involved in the project. BIM Maturity Level according to Oyesode *et al.* (2022) measures the degree of collaboration and information sharing between different stakeholders on any project. It is a measure of the quality, repeatability, and degree of excellence within a BIM capability (Taylor *et al*. 2012).

Many countries worldwide are at different stages of BIM implementation, leading to diverse experiences and knowledge across the Architecture, Engineering, and Construction (AEC) industry (Lepkova *et al.* 2019). In many developing countries, the adoption of Building Information Modeling (BIM) is still at an early stage. According to Oyesode *et al.* (2022), the BIM practices have not been embraced by the majority of construction entities in these nations. In addition, even the little utilization of BIM is limited to specific projects, particularly mega projects. This implies that most of the developing economies are still lagging behind the developed nations in deriving optimum benefits from BIM implementation. As a result, there is a need to establish the present BIM maturity of an entity to identify the present state of things and propose strategies for improvement to optimize BIM usage.

This has resulted in the introduction of various BIM maturity models and scoring systems by BIM scholars and experts to facilitate easy evaluation and measurement of BIM maturity

(Lepkova *et al.* 2019). These models can be broadly classified into two categories: one that assesses individual building projects based on their BIM utilization and one that evaluates the maturity of organizations in implementing BIM processes (Giel and Issa 2013). The objective of this study is to measure the BIM maturity levels of modular construction companies in Sub-Saharan Africa, thus the assessment will consider models that evaluate organizational maturity, taking into account the unique challenges and opportunities associated with modular construction. As a result, Succar's BIM Maturity Model Index (BMMI) was selected for this study.

Succar's BIM Maturity Model Index (BMMI) presents a practical way of measuring BIM maturity of organizations based on processes, technology, and policy as presented in Figure 1 (Succar 2009). According to Lepkova *et al.* (2019), BMMI is a highly flexible tool selected for BIM users who plan to implement or improve BIM implementations. It accommodates various users' objectives, covers multiple BIM aspects, easy to implement, and aligns BIM with organizational strategies (Taylor *et al.* 2012).

Figure 1. The three BIM maturity components (Succar 2009).

The model proposed three stages of BIM maturity. Stage 1, known as Object-based Modeling uses 3D parametric software tools (like ArchiCAD, Revit, Digital Project, and Tekla) for visualization and basic data exports. Stage 2, Model-Based Collaboration, involves interdisciplinary collaboration through model exchanges in both proprietary and non-proprietary formats, generating 4D and 5D studies. Stage 3, Model Server Technologies, utilizes advanced technologies for rich model integration and interdisciplinary analysis across project lifecycle phases, reflecting a high level of BIM integration and maturity (Succar 2009).

However, previous research on BIM maturity levels in different Sub-Saharan countries focused on specific construction professional firms, such as Architectural, Quantity Surveying, Project Managers, and Engineering firms, ignoring the unique challenges faced by modular construction firms (Mtya and Windapo 2019; Musyimi 2016; Oyesode *et al.* 2022; Pillay *et al.* 2018). As a result, this study aims to measure the BIM maturity levels of modular construction companies in Sub-Saharan Africa in order to establish the current state of things (strengths and weaknesses) in terms of BIM usage and provide insights that could enhance the adoption and integration of BIM in the modular construction sector of the region. The integration could further enhance project efficiency, reduce costs, and improve the quality of construction projects in the region.

2 RESEARCH METHODOLOGY

The research method for the study was divided into two parts. The first part comprised a literature review of related journals, articles, and conference proceedings to provide background information for the study. The literature reviews also guided the development of the research instrument adopted. The Succar (2009) BIM Maturity Model was selected due to its practical guidance to assess the BIM maturity of organizations. This was followed by developing a comprehensive table outlining the key aspects and indicators of BIM maturity levels based on the Succar (2009) model, ensuring clarity and categorization.

The developed questionnaire was administered online to modular construction companies within the Sub-Saharan African region. Focusing on modular construction companies is crucial due to the nature of modular construction, involving the complete manufacturing of building modules by the modular companies, setting them apart from traditional construction professionals. In addition, in modular projects, clients focus on the end product rather than the process, leaving BIM usage to the discretion of modular companies. Given the absence of a central database encompassing all modular construction companies in Sub-Saharan Africa, this research employed a purposive sampling approach. In this method, the selection of companies is deliberate and guided by specific criteria, including registration status, geographical location, and online availability. The respondents' modular construction companies should be fully registered in their host countries, be located within Sub-Saharan African countries, and be fully available online (website and social media). The justification for purposive sampling lies in its usefulness in studying a small subset of a larger population in which many members of the subset are easily identified but the enumeration of all is nearly impossible (Nayak and Singh 2015). Relying on registered companies online facilitates a systematic and comprehensive identification of potential participants.Top of Form The Unit of Analysis focused on BIM managers and industry professionals within chosen companies. Ultimately, 81 companies were identified through their websites and formed the study's sample frame.

Two modes of survey distribution were adopted – the fill-in PDF survey forms and online survey forms. The fill-in PDF survey form was sent as an email attachment to the identified domain modular companies, along with the link to the online survey form. Evans and Farrell (2020a) and Olawumi and Chan (2019) highlighted some benefits of these distribution modes, including time and cost savings and the ease of communicating and getting feedback from the survey participants. After multiple weekly reminders, a total of 31 valid responses were received in five weeks, representing a response rate of 38.3%.

The response rate looks low, however, the 31 responses were considered adequate for statistical analysis for several key reasons. First, Fellow and Liu (2003), as referenced by Musyimi (2016), suggest an acceptable response rate for online surveys in construction research of between 25% and 35%, which is in tandem with this study. Additionally, the sample size of 31 responses exceeds the threshold of 30 recommended by the central limit theorem for reliable conclusions to be made (Ott and Longnecker 2016 as cited in Wuni and Shen 2021). This aligns with similar international studies conducted using online surveys, where smaller sample sizes are common. For instance, published studies such as those by Sachs *et al.* (2007) with 27 responses, Ugwu *et al.* (2006) with 33 responses, Boz and El-Adaway (2015) with 15 responses, and Rajabi *et al.* (2022) with 31 responses. As a result, the responses received were considered adequate for statistical analysis.

3 FINDINGS AND DISCUSSION

3.1 *Demographic information of respondents*

Among the respondents, 58.1% are architects, engineers, designers, and quantity surveyors, emphasizing the importance of pre-project planning where these professionals are typically engaged. Other roles include project managers, BIM managers, managing directors, and contractors/sub-contractors. The distribution of company sizes reveals a notable emphasis on small and medium-sized enterprises, with 10 to 99 employees accounting for 58.1%. Large-scale companies account for 19.4%. Despite the emerging nature of modular construction in the region, the average modular construction of respondents is 6.3 years, indicating the respondents have adequate knowledge of the subject. BIM experience on the other hand has an average of 5.4years. This suggests well-informed opinions based on accumulated knowledge and experience.

3.2 *Level of understanding of Building Information Modeling (BIM)*

To test the respondents' knowledge of BIM, the respondents were asked to pick all that is applicable from the given options of BIM meanings. As shown in Table 1, the responses reveal diverse perspectives among the respondents. However, the most prevalent perspective, selected by 32.7% of respondents, interprets BIM holistically. They see BIM as encompassing all facets: technology, process, policy, and software. This comprehensive understanding reflects a detailed appreciation of the multifaceted nature of BIM. This suggests that all respondents, to some extent, understand what BIM entails, whether it be as a technological tool, a procedural approach, a set of guidelines, or a software application.

Table 1. Level of understanding of BIM.

BIM Meaning	Frequency	Responses percentage
BIM is a technology	14	25.5
BIM is a Process	10	18.2
BIM is a policy	6	10.9
BIM is a software	7	12.7
BIM is all of the above	18	32.7
BIM is none of the above	0	0.0
Total	55	100.0

3.3 *BIM maturity level of modular construction companies in Sub-Saharan Africa*

According to Succar (2009), the BIM maturity assessment comprises three stages, each characterized by distinct components of technology, process, and policy (TPP). The three components serve as a guide in our assessment of this objective.

3.3.1 *Technology field*

The technological aspects of BIM maturity consist of three critical elements: software, hardware, and network (Succar 2009). For this study, the assessment was limited to data-sharing networks and software used only due to the limitation of data availability for hardware, which can be considered secondary factors and supportive tools for software implementation.

3.3.1.1 *Platform for storing and sharing files* The respondents were asked to select all that apply from various platforms for storing and sharing project data. The responses received were summarized in Table 2. From Table 2, the significant adoption of cloud-based applications (35.9%) aligns with BIM Stage 1, suggesting a shift towards digital collaboration with improved data sharing and security, but unsystematic data exchange (Oyesode *et al.* 2022). Internal servers (16.7%) suggest a move to BIM Stage 2, having more systematic internal collaboration within the firm. External servers (5.1%) indicate BIM Stage 3 presence, emphasizing integrated model sharing and higher external collaboration. Hardcopy formats (24.4%) reflect lower technological maturity

3.3.1.3 *Software platforms available for use in firms and the extent of BIM usage* The study aimed to assess the availability and utilization of various BIM software platforms within firms. Respondents were asked to rank the availability and usage of these platforms on a 6-point Likert scale: 1 (Not used at all), 2 (0 - 20%), 3 (21 - 40%), 4 (41 – 60%), 5 (61 – 80 %), 6 (above 80%). The data collected were then presented in Table 3 below. The table shows

Table 2. The platform for storing and sharing files.

Data Sharing Platform	Frequency	Responses percentage
Cloud-based application (e.g. iCould, myCloud, GoogleDrive, etc)	28	35.9
Internal network-based server	13	16.7
External network-based server	4	5.1
Hardcopy format	19	24.4
Portable storage devices	14	17.9
Total	78	100.0

Table 3. Available software and their level of usage.

Code	Software Platform	Mean	Percentage (%)
P1	2D Drafting	4.5484	75.81
P2	3D Modelling	4.3548	72.58
P3	4D - Time (Scheduling)	2.8065	46.78
P4	Visualization	2.4516	40.86
P5	5D - Cost Analysis and management	2.2903	38.17
P6	Clash detection	2.0968	34.95
P7	Common data environment	1.8065	30.11
P8	IFC Generation	1.6452	27.42
P9	COBie	1.4839	24.73

that 2D Drafting (75.81%) and 3D Modeling (72.58%) are the most used software in modular companies, indicating that most are in the early BIM Stage 1, focusing on visualization (Oyesode *et al.* 2022). Advanced tools like 4D Scheduling, 5D Cost Analysis, and Clash Detection have lower usage (35-47%), suggesting a move towards BIM Stage 2, which involves more complex capabilities (Lepkova *et al.* 2019). Software for collaborative efforts and information sharing, such as IFC Generation, CoBie, and Common Data Environment, show the lowest usage (under 30%). These tools, associated with BIM Stages 2 and 3, indicate that few modular construction companies in Sub-Saharan Africa have reached these advanced stages (Haji *et al.* 2021).

3.3.2 *Process and policy field*

The respondents were asked to rank the availability and utilization levels of BIM processes and policy-related activities using a 6-point Likert scale, ranging from 1 (Not used at all) to 6 (Above 80%). The data collected for these fields are summarized in Table 4 below. From Table 4, process-related questions PP1 and PP4 had significant selections, at 65.05% and 52.15% respectively, indicating many companies have activities to enhance seamless data integration in modular construction projects, aligning with BIM Stages 1 and 2. Other process-related activities were below 50%, showing room for growth, especially in collaboration with internal and external stakeholders, crucial for BIM Stage 2. Organizational policies supporting BIM implementation ranged between 50-60%, suggesting moderate maturity with established standards, role definitions, and training mechanisms.

3.3.3 *Discussion of findings*

The study revealed that most modular construction companies in Sub-Saharan Africa are at BIM maturity stage 1, with some presence in Stage 2. The adoption of collaborative and information-sharing platforms remains limited, indicating potential areas for growth.

This agrees with the study of Lepkova *et al.* (2019) on the BIM implementation maturity for a developing economy, who found similar trends in Lithuania, where BIM Stages 1 and 2 are prevalent, but full technology integration is lacking. This was supported by Oyesode

Table 4. Level of BIM usage relating to process and policy.

Code	Process and Policy	Mean	Percentage (%)
	Organizational Processes		
PP1	BIM for initial planning of modular construction projects?	3.9032	65.05
PP4	Integration of BIM data across modular construction phases	3.1290	52.15
PP6	Use of BIM for stakeholder coordination	2.9677	49.46
PP7	Are there established processes for quality control using BIM in modular construction?	2.9032	48.39
PP8	How integrated are BIM processes with other project management systems	2.7419	45.70
PP9	Use of BIM for analytics and performance optimization in modular construction	2.7419	45.70
PP10	Management of BIM data exchange with external partners	2.5484	42.47
PP11	Use of BIM for lifecycle management in modular construction?	2.4839	41.40
	Organizational Policies		
PP2	Availability of established BIM standards for modular construction	3.6129	60.22
PP3	To what extent are BIM roles defined in your company?	3.4194	56.99
PP5	Established BIM training mechanism for modular construction teams?	3.0645	51.08

et al. (2022), who reported Nigerian architectural firms primarily at BIM Levels 0 and 1, with minimal presence at Levels 2 and 3, thus, recommending investments in IT infrastructure to support higher BIM maturity. The result is also comparable to the study by Musyimi (2016), who found the majority of construction management firms in Kenya at BIM level 1, with BIM usage limited to the design stage. BIM is mainly used as a drafting tool rather than a collaborative opportunity. As a result, the author suggested raising awareness of BIM's full project benefits.

Similarly, Jayasena and Weddikkara (2017) identified low BIM maturity as a peculiar scenario in the BIM infant industry. This was buttressed by Olugboyega and Oseghale (2023), Saka and Chan (2020), and Belay *et al.* (2021), who noted that BIM maturity is low and uneven among large and medium enterprises in developing nations. Most Sub-Saharan African countries are categorized as developing, thus aligning with this study result.

As a result, to solve the lower degree of BIM implementation and maturity in modular construction in Sub-Saharan Africa, it is necessary to focus on the overall condition of BIM implementation among modular construction firms operating within the region. This approach will provide a clearer picture of BIM use and help identify region-specific strategies to overcome adoption challenges.

4 CONCLUSION

The effectiveness of Building Information Modeling (BIM) in any project depends on how comprehensively it is implemented. This is a measure of the various BIM operators and stakeholders involved. Countries worldwide are at different stages of BIM adoption, leading to diverse experiences. This study evaluates the BIM maturity levels of modular construction companies in Sub-Saharan Africa. The aim is to gain a clearer understanding of the existing situation and provide insights that could enhance the adoption and integration of BIM in the modular construction sector of the region.

The study revealed that the majority of modular construction companies in Sub-Saharan Africa are predominantly at the initial stages of BIM Maturity (Stages 1 and 2), which are BIM Levels that fail to maximize the advantages of BIM tools and processes, thereby hindering the optimization of modular construction potential benefits when using BIM. The study therefore recommends that Sub-Saharan African modular companies invest more in technological infrastructure that would be capable of supporting BIM implementation for significant inherent benefits of BIM to be maximized by them. In addition, the companies are encouraged to pursue early adoption of BIM initiatives at the planning stage of modular project development.

However, the uneven distribution of modular construction firms and the difference in BIM maturity among different Sub-Saharan countries presents limitations. Most of the medium and large-scale modular firms are concentrated in a few countries with many countries within the region lacking the presence of modular firms entirely. This resulted in a relatively small sample size and response rates for the whole region.

Future research could investigate the adoption of other smart technologies in modular construction projects throughout the region, potentially offering further enhancements in efficiency and effectiveness.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Critical factors influencing the selection of sustainable materials for residential building projects: A literature review approach

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ABSTRACT: This review explores the critical factors influencing the selection of sustainable materials for residential building projects, with a particular focus on developing countries. With the aid of MS Excel and Mendeley Reference, the articles from 2014 to 2024 were analyzed through a rigorous PRISMA-based methodology to synthesize 7 environmental, 7 social, and 5 economic key determinants of sustainable building materials from various accredited sources. This review reveals intriguing patterns in publication trends, geographical distribution, and methodological approaches. The findings will aid key stakeholders to make informed decisions with practical benefits such as cost savings, enhanced community engagement, and improved environmental outcomes. This review urges future studies to focus on incorporate theories and frameworks that account for the unique socio-economic and environmental dynamics relevant to developing countries. Also, future studies should focus on a more inclusive approach for literature synthesis as a gap presented in this review.

Keywords: Sustainable Materials, Material Selection, Residential Building Projects, Sustainable Construction, Review

1 INTRODUCTION

The provision of sustainable housing in developing countries is not as effective as in their western counterparts. (Dosumu and Aigbavboa 2018) found that apart from the general challenges associated with the adoption of sustainable design and construction, factors such as poverty, fear of change, corrupt governments, and environmental are serious problems to achieve sustainable housing in African countries. In Tanzania, the construction sector significantly contributes to the GDP, accounting for 14.4%, despite a growing population and urbanization pressures (Likhacheva *et al.* 2019; NBS 2021). However, the increasing demand for housing and infrastructure poses challenges, necessitating the use of sustainable and cost-effective building materials (Worrall *et al.* 2017). Though the long-term economic benefits of sustainable buildings are undeniable, the higher upfront costs of sustainable building materials hamper their effective adoption in developing nations (IEA 2019). Therefore, developing sustainable residential housing in the developing nations like Tanzania requires a different approach from that used in the developed world such as reliance to alternative building materials in their development (Makenya and Nguluma 2015)

(Ding 2014) defines SBMs as materials produced, used, and disposed of in a way that minimizes their environmental impact while also promoting social and economic sustainability. (Ross and Dru 2012) adds that sustainable building materials are a key component of green buildings, which are designed and constructed with a focus on reducing their environmental impact and promoting sustainability. According to (Bal *et al.* 2013), the selection

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of SBMs is a vital task for building construction projects since it guides the stakeholders not only to fulfill their sustainability duties but also to maximize tangible benefits of the concept. (Akadiri and Olomolaiye 2012) add that the principal challenge is the identification of assessment criteria based on the concepts and principles of sustainability, and the process of prioritizing and aggregating relevant criteria into an assessment framework. There is therefore the need to develop a systematic and holistic selection process of identifying and prioritizing relevant criteria and evaluating trade-offs between environmental, economic, social and technical criteria. It is however, worth-noting that existing sustainability assessment tools are usually not compatible with geographical situation, specifically in African developing countries, due to variance in the climatic conditions of developed and developing countries, cultural differences and assumptions that electricity supply is constant (Dosumu 2018).

The selection of SBMs and their use are still limited in driving sustainability in building construction projects in most developing nations as introduced earlier (Eze *et al.* 2023; The United Republic of Tanzania 2017). Various authors wrote on common obstacles of proper integration of sustainable building materials (SBMs) in construction practices of developing countries. (Ahmet and Mujde 2019; Eze *et al.* 2023) highlighted barriers such as resistance to change, limited awareness (information gaps), lack of regulation and funding, high costs, small markets, lack of government incentives, shortages of experts and labor (technical limitations), and building codes that do not accommodate alternative materials. In Tanzania, western-made materials are often preferred, seen as symbols of wealth and modernization, which hinders the choice of local alternative materials (Makenya and Nguluma 2015). Hence, understanding the criteria used to assess sustainability of building materials within the context of Tanzania is crucial in order to influence the informed decision-making of stakeholders and consequently, to maximize the benefits of integrating sustainable materials in the development of residential building projects.

Although various studies have been conducted to provide solutions aimed at addressing these challenges, the knowledge contribution is still limited and discussions often remain superficial, lacking a proper guide of the contextual factors at play. This review aims to explore critical factors that influence the selection of sustainable materials for residential building projects, with a particular focus on developing nations. The very first step was to search the literature that guided authors to understand the state of the subject matter and its development to this date. The next step focused on classifying the identified factors under the 3 pillars of sustainability, namely environmental, social, and economic. From there, the literature was mapped to synthesize the most critical factors for each category.

2 METHODOLOGY

2.1 *Introduction*

Through an SLR, a comprehensive overview of the existing research enables to identify the critical factors influencing the selection and use of sustainable building materials. (Petticrew and Roberts 2006) indicates that systematic reviews play a pivotal role in synthesizing evidence from multiple studies, reducing biases inherent in narrative reviews, and contributing to evidence-based decision-making. As reported by (Trisha and Peacock 2005), systematic reviews are crucial for uncovering patterns, inconsistencies, and gaps within the existing body of knowledge, thereby guiding future research endeavors. For this particular work, the review process followed existing guidelines of PRISMA Framework (Moher *et al.* 2009), for the systematic reviews and encompassed several key stages. As detailed below, the applying stages include (1) Search Strategy, (2) Selection Criteria (Inclusion & Exclusion), (3) Quality Assessment, and (4) Data Extraction. Additionally, the data extracted from the selected articles were analyzed using qualitative content analysis, supported by Mendeley Reference Manager & MS Excel. These tool facilitated the coding and thematic analysis of the data, allowing for the identification of recurring themes and patterns across the studies.

2.2 *PRISMA framework key stages*

2.2.1 *Search strategy*

For the purpose of this systematic search, the relevant literature was identified through a search strategy. The search strategy took into account major E-Resources such as: Emerald Insight, Science Direct, Research4Life, and Google Scholar. From Table 1, the useful databases can be seen with the links to their Web Pages as well as keywords that was used for each database. Lastly, the search was conducted for articles published within the last decade, from 2014 to 2024, ensuring a contemporary and comprehensive coverage of relevant research on this particular subject. *Selection Criteria*: The phase of inclusion and exclusion criteria followed the PRISMA Chart (Moher *et al.* 2009). The scope of selection encompasses conference papers and journal articles published between 2014 and 2024. Moreover, only English-written publications were included. Apart from the fact that the Search String had to appear in the title of the articles, only peer-reviewed research articles within the fields of Architecture, Engineering, Material Science, and Environmental Sciences were considered. For the purpose of diverse perspective, publications from both developed and developing countries were considered in order to maintain the balance. At this stage, 140 articles out of 174 records were excluded. More details about the inclusion and exclusion criteria are provided in Table 2 below.

Table 1. Search databases & networks.

Database/Network	Web Page	Search Text
Emerald Insight	https://www.emerald.com/insight/	Sustainable building materials “AND” Residential building “AND” Selection “AND” Criteria
ScienceDirect-Elsevier	https://www.sciencedirect.com/	Sustainable building materials “AND” Residential building “AND” Selection “AND” Criteria
Research4Life	https://portal.research4life.org/	Sustainable building materials “AND” Residential building “AND” Selection “AND” Criteria
Google Scholar	https://scholar.google.com/	Criteria “AND” Sustainable building materials selection “AND” Residential building project

Table 2. Selection criteria.

Inclusion	Criteria
Inclusion	Keywords found in the title of the articles Peer-reviewed publications Search fields of Architecture, Engineering, Material Science, and Environmental Sciences Availability to accessible databases and journals Conference papers or journal articles Publications made between 2014-2024 Only English-written publications
Exclusion	Articles: published before 2014; whose Search String not found in the article title; other than English; can’t be fully accessed; and not oriented to building projects

2.2.2 *Quality assessment*

In order to maintain the rigorousness of the academia, articles from predatory journals and databases were excluded to ensure a robust synthesis of reliable and high quality insights of the subject matter. More of quality assessment tasks were performed such as eliminating the duplicates, check-up of the abstracts for the analysis and purification of the articles to ensure that the quality and relevance in review process are achieved. The next exclusion criteria were to disallow articles written in language other than English, and those whose search string not oriented to building projects. At this stage, only 24 articles remained candidates of extraction, that's before 4 more publications had to be removed for being published in predatory journals or database. That makes it 20 articles worth the final inclusion of this systematic review.

2.2.3 *Data extraction*

From Figure 1 below, only 20 articles were selected for the analysis after all aforementioned criteria were considered.

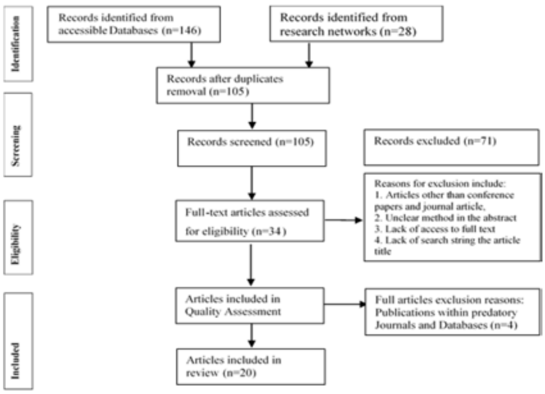

Figure 1. PRISMA framework.

3 RESULTS AND INTERPRETATION

3.1 *Descriptive analysis*

The analysis of selected publications unveils intriguing patterns in the research concerning determinants of sustainable materials selection within the last 10 years. While there is a noticeable surge of publications in 2021 with 6 papers as the highest of number published within a year, the publication trend in the remaining years indicates a fluctuation varying between 1 and 3 (Figure 2). Geographical distribution highlights a diverse representation which underscores the global interest of the subject. China and Iran emerge as prominent contributors with an equal contribution of 15% for each, while the rest of other countries contributed 5% to 10%, each (Figure 3).

Figure 2. Records distribution per year.

Figure 3. Records distribution per country.

A balanced representation can be seen in terms of income categories of the participating countries with the majority of articles originating from Upper-Middle-Income (5) followed by Lower-Middle-Income (4), High Income with 3, and Low Income with 1. High Income countries include: Australia, Finland, and Saudi Arabia; Upper Middle Income nations include China, India, Iran, UAE, and Malaysia; Lower Middle Income countries are Nigeria, Ghana, Egypt, and Tanzania; while the only Lower Income nation participating is Ethiopia (The World Bank 2023). Notably, Journal articles (95%) constitute the most preferred mode of publication compared to Conference publications with 5%, affirming the scholarly depth and rigor of the included literature (Figure 4). On the other hand, Mixed and Quantitative were the most used method having the number of 8 articles for each, while Literature review was the least employed with 1 article (Figure 5). This attests to the interdisciplinary nature of research endeavors in the subject. Lastly, Mixed and Quantitative were the most used method having the number of 8 articles for each, while Literature review was the least employed with 1 article (Figure 5). This attests to the interdisciplinary nature of research endeavors in the subject.

Figure 4. Publication type representation.

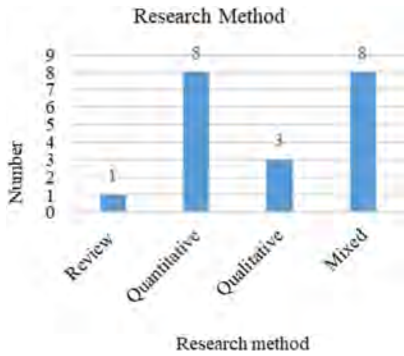

Figure 5. Research methods.

3.2 *Thematic analysis*

Generally speaking, close to all twenty articles included in the review, highlighted the growing interest among researchers in exploring the subjects related to the selection of sustainable construction materials. The later relates to the findings of (Fertoli *et al.* 2022), which revealed that sustainability is no longer a choice but a necessity. It was as also realized that the majority of the selected studies, emphasized on the importance of utilizing Multi-criteria decision-making (MCDM) approaches in the assessment of the criteria influencing the selection of sustainable building materials. This is so true because it allows decision-makers to consider various criteria, such as environmental, economic, and social factors in the material selection process (Shervin *et al.* 2023). Lastly, 7 environmental critical factors, 7 social critical factors, and 5 economic critical factors influencing the selection of SBMs for residential building projects were synthesized from the 20 selected articles as provided in the Table 3 below.

3.3 DISCUSSION

This systematic review evaluates existing research on the factors influencing the selection of sustainable materials for residential building projects, with an emphasis on their applicability in developing countries. While this study does not introduce new empirical data, it offers a

Table 3. Critical factors influencing the selection of sustainable materials for residential building projects.

ENVIRONMENTAL KEY FACTORSTORS (EKF)		
EKF 1	Environmental Statutory Compliance	(Agyekum, *et al.* 2022; Eze *et al.* 2022; Moradi and Kalle 2022; Mathiyazhagan *et al.* 2019; Mayhoub *et al.* 2021)
EKF 2	Resource Efficiency	(Agyekum *et al.* 2022; Chen *et al.* 2015; Mayhoub *et al.* 2021; Mushi *et al.* 2023; Tegegne *et al.* 2023; Zhang *et al.* 2017)
EKF 3	Energy Efficiency	(Agyekum *et al.* 2022; Chen *et al.* 2015; Govindan *et al.* 2016; Moradi and Kalle 2022; Mahmoudkelaye *et al.* 2018; Sahlol *et al.* 2021; Zhang *et al.* 2017)
EKF 4	Waste Management	(Al-Atesh *et al.* 2023; Govindan *et al.* 2016; Mathiyazhagan *et al.*, 2019; Mayhoub *et al.* 2021; Moradi and Kalle 2022; Oladokun *et al.* 2021; Sahlol *et al.* 2021; Tegegne *et al.* 2023)
EKF 5	Protection of Eco-systems	(Chen *et al.* 2015; Eze *et al.* 2022; Mushi *et al.* 2023)
EKF 6	Material Environmental Impact	(Chen *et al.* 2015; Mahmoudkelaye *et al.* 2018; Makenya and Huba 2017; Tegegne *et al.* 2023)
EKF 7	Climate Compatibility	(Chen *et al.* 2021; Mahmoudkelaye *et al.* 2018; Makenya and Huba 2017; Mathiyazhagan *et al.* 2019; Tegegne *et al.* 2023)
SOCIAL KEY FACTORS (SKF)		
SKF 1	Preservation of Cultural Identity	(Almahmoud and Hemanta 2020; Chen *et al.* 2021; Moradi and Kalle 2022; Mathiyazhagan *et al.* 2019; Mahmoudkelaye *et al.* 2018)
SKF 2	Health and Safety of Users	(Chen *et al.* 2015; Govindan *et al.* 2016; Karji *et al.* 2019; Mathiyazhagan *et al.* 2019; Moradi and Kalle 2022; Rostamnezhad and Muhammad 2022; Sahlol *et al.* 2021; Tegegne *et al.* 2023)
SKF 3	Collaboration and Knowledge Sharing	(Almahmoud and Hemanta 2020; Fatourehchi and Esmaeil 2020; Mayhoub *et al.* 2021; Mahmoudkelaye *et al.* 2018; Moradi and Kalle 2022; Oladokun *et al.* 2021; Rostamnezhad and Muhammad 2022)
SKF 4	Aesthetics	(Govindan *et al.* 2016; Fatourehchi and Esmaeil 2020; Mathiyazhagan *et al.* 2019; Mayhoub *et al.* 2021; Mathiyazhagan *et al.* 2019; Tegegne *et al.* 2023)
SKF 5	Supporting Local Economy and Human Resource: Sourcing building materials locally and utilizing local expertise and labor	(Al-Atesh *et al.* 2023; Almahmoud and Hemanta 2020; Eze *et al.* 2022; Govindan *et al.* 2016; Karji *et al.* 2019; Mathiyazhagan *et al.* 2019; Makenya and Huba 2017; Moradi and Kalle 2022; Mahmoudkelaye *et al.* 2018; Oladokun *et al.* 2021; Rostamnezhad and Muhammad 2022; Tegegne *et al.* 2023)
SKF 6	Stakeholders Involvement	(Chen *et al.* 2015, 2021; Moradi and Kalle 2022; Oladokun *et al.* 2021; Rostamnezhad and Muhammad 2022
SKF 7	Regional Availability and Adaptability	Al-Atesh, *et al.* 2023; Karji *et al.* 2019; Mathiyazhagan *et al.* 2019; Makenya and Huba 2017; Mushi *et al.* 2023)
ECONOMIC KEY FACTORS (EKF)		
EKF 1	Total Life Cycle Cost: Overall Cost Used During the Building Life Span	(Al-Atesh *et al.* 2023; Chen *et al.* 2015; Govindan *et al.* 2016; Mathiyazhagan *et al.* 2019; Mahmoudkelaye, *et al.*, 2018; Moradi and Kalle 2022; Oladokun *et al.* 2021; Sahlol *et al.* 2021; Tegegne *et al.* 2023; Zhang, *et al.*, 2017)
EKF 2	Energy Saving (Cost of Energy During Production and Transportation	(Chen *et al.* 2015; Eze *et al.* 2022; Mathiyazhagan *et al.* 2019; Mayhoub *et al.* 2021; Oladokun *et al.* 2021)
EKF 3	Stakeholder's Satisfaction (Client, Supplier, Employee)	(Al-Atesh, *et al.* 2023; Chen *et al.* 2015; Govindan *et al.* 2016; Moradi and Kalle 2022; Oladokun *et al.* 2021)
EKF 4	Affordability and Cost-Effectiveness	(Al-Atesh *et al.* 2023; Chen *et al.* 2015; Mathiyazhagan *et al.* 2019; Mayhoub *et al.* 2021)
EKF 5	Market Availability and Accessibility	(Mahmoudkelaye *et al.* 2018; Moradi and Kalle 2022; Mathiyazhagan *et al.* 2019)

synthesis and analysis of the findings from previous studies, providing valuable insights into the current state of knowledge in the field.

As introduced earlier, in many developing countries, rapid urbanization and population growth intensify environmental concerns and resource constraints (Raed and Monjur 2017). The findings of this review suggest that considering environmental factors such as proper waste management, energy-efficient materials, resource efficiency, the use of low environmental impact materials, and environmental statutory compliance in the selection of SBMs would promote resource conservation in resource-constrained settings, save rising energy costs, and increase the owners' preference for green buildings in developing countries, aligning with claims (Bampou 2017). As claimed by Passos Neto *et al.* (2023), integrating social considerations into material selection decisions allows stakeholders to ensure that construction projects contribute to the well-being and prosperity of local communities. This review highlight key factors from selected studies such as preservation of cultural identity, health and safety of users, collaboration and knowledge sharing, aesthetics, utilizing local expertise and labor, stakeholders' involvement, regional availability and adaptability, and the use of locally sourced building materials that are not only affordable and accessible compared to conventional materials but also environmentally friendly and climate-adaptive (UNEP 2022). Incorporating such factors in material selection processes promotes sustainable development in developing countries, as stressed by UN-Habitat (2015). The financial aspect is a critical factor in the selection of SBMs in developing countries, given their perceived high up-front costs. (Onuoha, *et al.* 2017) denote that developers in Africa are most concerned with cost savings factor as a determining factor in the pursuit of green building projects. Similarly, (Simpeh and Smallwood 2020) noted that financial benefits were the most influential factor linked to the clients' or stakeholders' decision to adopt green buildings. This reviews identifies total life cycle cost, cost of energy during production and transportation, market availability and accessibility, and stakeholder's satisfaction as key determinants for the selection of SMBs particularly in the context of developing world. To close this section, it is essential to say this review show the multifaceted nature of sustainable material selection for residential building projects in developing countries. By considering the findings of this review, stakeholders such as developers, building professionals, and policymakers can make informed decisions with practical benefits such as cost savings, enhanced community engagement, and improved environmental outcomes. To researchers, this is a reminder to focus on providing clear guidance for stakeholders to implement more sustainable practices in the selection of building materials for residential buildings in developing countries.

3.4 *Research gap*

Though the search and inclusion of relevant literature from various sources were done diligently, it is however crucial to recognize that our findings were influenced by the availability and accessibility of published studies. This limitation could affect the generalizability and validity of our conclusions, as it may not fully capture the spectrum of research findings and perspectives on sustainable material selection. Therefore, future research should focus on a more inclusive approach for literature synthesis.

4 CONCLUSION

The rapid urbanization and population growth in developing countries increase environment concerns and resource depletion which calls for immediate sustainable solutions, particularly the reliance on the sustainable and cost-effective building materials in housing development. This systematic review aimed to identify critical factors influencing the selection of sustainable materials for residential building projects, with contextual emphasis of the developing world. Through PRISMA Framework, 20 publications from 2014 to 2024 that were analyzed for the purpose of this review. Descriptive analysis reveals a growing interest in the field of sustainable material selection in both middling and developing countries, with an upward trend of publications in recent years. The thematic analysis identified 7 environmental, 7 social, 5 economic key determinants influencing the selection of sustainable building materials for residential building projects. It also reveals the vital role of utilizing Multi-criteria decision-making (MCDM) approaches in the assessment of the criteria influencing the selection of SBMs as the method allows decision-makers to consider various criteria, such as environmental, economic, and social factors in the material selection process. While this review acknowledges the relevance previous studies on sustainable material selection in developing countries, many discussions often remain superficial, lacking a nuanced understanding of the contextual factors at play. It therefore recommends future research to incorporate theories and frameworks that account for the unique socio-economic and environmental dynamics relevant to this context. To developing countries, promoting locally sourced materials would lessen arising resource scarcity, rise community well-being with an increased affordable housing.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Design and construction material related factors influencing the selection of contract procurement method in Kwazulu-Natal province in South Africa

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ABSTRACT: A study of kwazulu-Natal province, South Africa was undertaken. The target population of the study were professionals in the construction field, the Architects, Project managers, Quantity surveyors, Engineers and Contractors, A sample of 65 professionals was surveyed, and data was analyzed using descriptive analysis method of selecting of respondent. The reliability of this study was confirmed using a Cronbach alpha coefficient of 0.70. Findings for this study are design team experience, project design complexity, mistakes in producing design documents, wastage of construction materials, shortage of construction materials and late ordering materials are factors that influence the selection of a contract procurement strategy. The recommendations are that scope and budget of the project, quality and risk plan are the foremost factors for consideration for selection of a procurement strategy in project delivery.

Keywords: Procurement method, project management, Project delivery, Project scope

1 INTRODUCTION

Construction industry is a complex and fragmented type of industry in terms of supply chain, products and processes and is faced with a dilemma such as that of manufacturers and whose productivity and efficiency is measured through its triple constraints (Kabirifar and Mojtahedi 2019).

Practitioners and academics noted that most of the problems in construction projects are from inadequate procurement procedures where more focus was on short term individual sub optimization rather than long term project team performance, an improvement of procurement procedures is therefore needed so as to increase the efficiency and development of construction industry (Eriksson and Westerberg 2009). Construction industry is to play a significant role in achieving the sustainable and development goal and a more active role in partnering with industry stakeholders. (Opoku *et al.* 2022)

Eriksson and Westerberg (2009) further stated that the higher the level of collaboration between client and contractors in the design stage, it may lead to success in the following areas of project performance; economical performance, time performance, quality of products, environmental performance, work environment and product, process innovation.

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2 LITERATURE REVIEW

2.1 *Design related factors influencing the selection of a contract procurement strategy in project delivery*

2.1.1 *Design team experience*

The design team characteristics are latent variables which are used to measure a design team's performance in the early design stages. These variables are reflected in six observed main factors, they are skill, experience, communication, collaboration, innovation and procurement. The higher the design team's skills, the more experienced the design team was, also, the less communication channel, the better potential risks and uncertainty are mitigated during the construction phase (Hu and Skibniewski 2022). Design team tends to see aesthetics as more paramount than other factors in construction including procurement strategies and that has resulted into numerous problems (Larsen and Whyte 2013).

2.1.2 *Project design complexity*

The amount of projections and curves in a structure and their level coupled with the amount of details provided of a project indicates its level of complexity. Larson and Whyte (2013) conducted (Kumar *et al.* 2016)an empirical analysis and found that the design produced, the design team and their experience have an important role to play in design procurement and safety.

2.1.3 *Mistakes in producing design document*

Mistakes in designs are sometimes caused by non-existence of rules that should prevent architectural mistakes or existence of rules that leads to mistake in design and authentication of such mistakes by design related governmental parties. Such mistakes in already authenticated designs have effects and tendencies to become acceptable in the society and more likely to be repeated and propagated by designers. Mistakes in design documents are mainly from three parties which are designers, executers and clients, but the designers are mostly responsible as they know more of the nature of the mistake than others and are also the reference of solutions (Qaradaghi and Abdullah 2020). (Kumar *et al.* 2016)

2.1.4 *Delay in producing design documents*

There are many reasons that could cause a delay to arise from the production of design documents. Argument and indirect disagreement between the Client and Architect during the design and conceptual development phase. The disagreement could arise if the project objective is not being understood between one of those parties and also due to lack of proper communication. Cultural difference could occur due to differences in habit, religion, tradition. Incomplete drawings, inconsistent detailing of drawing, incorrect dimensions, and discrepancies of contract documents are major factors that could also cause a delay in producing design documents which in turn influence the selection of a contract procurement strategy (Atout 2016).

2.1.5 *Design approval delay by client*

Client delays in design approval can stem from a number of things, such as requirements revisions, indecision, poor communication, complexity of the project, lack of client experience, and bureaucratic processes. It is vital to comprehend these causes in order to choose a suitable contract procurement approach. Delays in project completion might be attributed to clients who are unclear about their requirements or lack a clear vision for the project. clients find it difficult to make decisions, unclear expectations frequently lead to numerous modifications and prolonged approval times (Assaf and Al-Hejji 2006).

2.1.6 *Inadequate coordination among designers*

It is worth noting that an improper coordination amongst designers could influence the selection of contract procurement strategy. Missing part of design document may not afford a wholestic review of the quantity of work and purpose of design to enable the selection of a procurement strategy. Therefore it is recommended that the design manager and resident engineer should ensure that their team members apply all techniques of design management process during design and construction phase. The design team should have contractual, technical and financial experience and expertise in construction projects and the consultancy firm in relation to the production of the design document must appoint an experienced and qualified design manager to coordinate and communicate with the project design team and other project stakeholder more importantly the client and the architect to ensure that the project objectives are clear between all parties and is achieved according to the client requirement. (Atout 2016).

2.1.7 *Revision and changes order by client*

Client's change of design and specification are one of the factors which causes errors in contract documents. Frequent design changes by clients will send designers back to the drawing board to redesign and the Quantity surveyors would have to prepare the bill of quantities again and when these process occurs repeatedly there tends to be mix-ups that may lead to misinterpretation of intended interest or intention relative to purpose. This may eventually lead to designs of structures either too large or small and not meeting functional requirement and hence an incorrect procurement strategy being selected. Revision and changes order by clients could also make designers maneuver their way and violate rules and procedures of contract documentation (Dosumu *et al.* 2017).

2.2 *Construction material related factors influencing the selection of a contract procurement strategy on project delivery*

2.2.1 *Unsuitable locations for material storage on site*

Misron *et.al.* (2018) defined workflow of material storage management as the criteria of management work forms that are replicated in a process and is a guide to the work process that should be carried out by the construction parties involved. The workflows are planning and arrangement, implementation and handling, controlling and also supervision and monitoring. When a site is congested such as having limited space, poor site productivity, impaired site security and irregular systems, these have negative impacts on construction material storage on site as access to site is restricted. These factors are considered in the selection of procurement strategy.

2.2.2 *Late delivery of construction materials*

Competence of procurement officer, quality, transportation and housing were identified to be some major factors affecting materials delivery on construction sites, that in term dictates procurement strategy. Procurement officers are needed to be trained to have good pricing and negotiation skills and also a proper relationship is to be built between construction firms, procurement officers and suppliers so as to foster right communication, improve service delivery and timely receiving of construction material. Electronic material procurement should be used more by construction firms as this would enhance and improve effective construction material procurement on construction sites. (Shittu *et al.* 2022).

2.2.3 *Wastage of construction materials by workers*

Construction material is being wasted when it is not properly managed. Material management strategies can be referred to as scientific techniques that involve planning, acquiring, selecting, purchasing, transporting, storing and moving of materials. It is a core process in engineering, procurement and construction companies with multiple modules. Implementing the strategies covers lost time, minimizes lost materials and provides the most efficient operation plan. The indicators of material management are inventory control, inbound logistics and quality control. These are strategies that will afford effective control and are to be considered in the selection of procurement strategy that will mitigate wastage of materials. Construction material wastage is one of the factors which leads to failure or delay in project as construction material and equipment contributes 70 percent of the total construction project cost. (Sila and Gakobo 2021)

2.2.4 *Shortage of construction materials*

The primary factor contributing to the shortage of resources is the source or accessibility of building supplies. On the other hand, inadequate inventory management and materials procurement systems, which have other underlying causes such delayed identification of the type of materials required, were noted to be the most significant source of delay and shortage in material supply (Rahman *et.al.* 2017). A storage system that will afford the usage of materials in compliance to the principle of first in first out should be employed. Different materials have their specific way of storage in order to eliminate damages or reduces damages to minimum. A good example is cement.

2.2.5 *Difficulties in obtaining materials from store due to excessive paper works*

A lack of departments concerned with materials in construction companies, consultancy firms, manufacturers and suppliers, gives an indication that materials which are estimated at about half of any construction's cost are not given enough attention, despite their importance (Salah and Steve 2014). Paper work must be made simple and fast to enable the release of materials for use. A complex process may negatively affect productivity and the materials itself.

2.2.6 *Increase in cost of construction materials*

A suitable procurement is essential for managing project pricing, A good estimating model is better utilized and special attention given to price variableness and engineers' estimate as these aspects are critical to address vagueness of procurement selection criteria to further reduce complications during evaluation. The factor of concern when utilizing procurement function to manage tender-price variability and inflation includes two indicators related to a government function. It was deduced that the critical indicators include benchmarking price performance and eliminating errors in tender documents. There is therefore a need to establish a public procurement strategy for managing construction price variability and inflation by modeling for fundamental principles such as value for money, benchmarking price performance, and reducing tendering documentation errors, that collude and conspire to impact price inflation, client perception and infrastructure push, and public accountability. (Tembo *et al.* 2023)

2.2.7 *Late order of construction materials*

Poor inventory management and materials procurement practices, which also have other underlying causes such delayed identification of the type of materials required, were determined to be the most significant source of delays in the supply of materials (Rahman *et. al.* 2017).

The late ordering of construction materials may be a factor that causes increased project final cost. The principle of purchasing upfront 70% of materials for the project eliminates inflation and price changes.

2.2.8 *Unsuitable locations for material*

Congested sites may have a negative impact on storage of materials such as restricted site space to the source of storage space is also limited, site productivity is weak, construction site security is also affected and irregular management system. Material manager should include collaboration with the designer on the specification of the material component, purchasing the right material to assist the changing of supply source location, inbound traffic, acceptance and inspection, supplier quality control, inventory control and material control. On larger build sites, material managers should be assisted by suppliers (Misron *et.al.* 2018). The sources of material purchase for a project may adversely affect condition of materials delivery and cost of materials. In cases where the source of materials are far from project location bulk purchase is recommended.

3 RESEARCH METHODOLOGY

A questionnaire survey was conducted for this study. A total of sixty five (65) questionnaires were administered to construction professionals (Architects, consultant Quantity surveyors, contracting Quantity surveyors, project managers, contractors and others) in KwaZulu Natal Province. Forty five (45) questionnaires were administered in person to the respondents, out of which thirty one (31) questionnaires were duly completed and retrieved. The remaining questionnaires were administered via electronic email.

The respondents in the study held different positions in various firms. The participants' firms include Contracting firms (19.61%), Architectural firms (11.76%), Project management firms (21.57%), Quantity surveying firms (9.80%), client (13.73%) and Engineering firms (17.47%). Most of the respondents have bachelor's degree qualification (45.1%), Honours (17.65%). The average years of experience of respondents is 11-15 years and most of the respondents have worked for both public and private organisations. The first section of the questionnaire dealt with the respondents general information, the second section comprises sub sections that addresses the objective of the research with the aim of examining the perception of respondents on the effectiveness of contract procurement strategies and also factors influencing the selection of a suitable procurement method.

Simple statistical tools such as the mean score and standard deviation were used for the statistical analysis of data. Based on the result of the analysis of data, conclusion and recommendation were drawn. Hence, the respondents were able to provide valid and reliable information based on the knowledge acquired from different firms.

4 DATA PRESENTATION AND ANALYSIS

Table 1 presents design related factors influencing the selection of contract procurement strategy. It is worth noting that all factors have a MS above the midpoint of the scale (2.5) except delay in producing design documents (2.35). These indicates that the factors have moderate to major influence to be considered for selection with respect to design related factors in the selection of procurement strategy. Design team experience with a MS = 4.51

Table 1. Design related factors influencing the selection of a contract procurement strategy on project delivery.

S/N	Factor	Mean score	Standard deviation	Rank
1	Design team experience	4.51	0.294	1
2	Project design complexity	4.32	0.268	2
3	Mistakes in producing design documents	4.26	0.153	3
4	Revision and changes order by client	3.15	0.111	4
5	Inadequate coordination among designers	2.72	0.075	5
6	Design approval delay by client	2.52	0.014	6
7	Delay in producing design documents	2.35	0.012	7

has the highest rating. Experience of individuals assist in deducing the possibilities of the project being procured or not. There are levels or types of experience that individuals have acquired and are relative to specific residential, office block, hospital construction, tall and framed structures. These must be identified and considered about the design team experience and may be the reason for those rating.

Next to Design team experience is Project design complexity with a MS = 4.32. This factor aligns with the design team experience. A complex project will require professional with reciprocal amount of experience to design. Professionals that have handled such complex project and have adequate experience are preferrable for such design requirement.

Next to project design complexity is Mistakes in producing design documents with a MS = 4.26. Mistakes in the construction industry either regarding construction or design documents are very costly. The principle of right first time is always adopted regarding work in the construction industry. This factors must guide the selection of procurement strategy in order to mitigate cost increase , accidents leading to fatalities, reworks and associated factors.

The least factor to be considered regarding design related factors when considering procurement strategy selection is Delay in producing design documents MS = 2.35. Delay in producing design documents may not have a serious impact in the delivery of a project. As this delay may not be beyond two weeks. Other activities may continue on site without adversely impacting in the project speed. This may be the likely reasons for the rating. The second to the least rated factor is Design approval delay by client with a MS = 2.52. Design approval delay by client has a minor influence on the procurement strategy selection.

Table 2 reveals the construction materials related factors that influence procurement strategy selection. The factor with the most rating is wastage of construction materials by workers with an MS = 4.85. Strategy must be involved to mitigate material wastage during application, cutting and storage. These have a cumulative adverse effect on contractor's profit margin.

Table 2. Construction material related factors influencing the selection of a contract procurement strategy on project delivery.

S/N	Factor	Mean score	Standard deviation	Rank
1	Wastage of construction materials by workers	4.85	0.109	1
2	Shortage of construction materials	4.70	0.150	2
3	Late order of construction material	3.61	0.333	3
4	Difficulties in obtaining materials from store due to excessive paperwork	3.22	0.391	4
5	Increase in cost of construction materials	3.28	0.381	5
6	Late delivery of construction materials	2.22	0.538	6
7	Unsuitable locations for material storage on site	1.37	0.663	7

Next to wastage of construction materials by workers is Shortage of construction materials with an MS = 4.70. Materials shortages on site may be relative to two factors, they are; inexperience of the site manager or lack of adequate funding by client. Site manager should involve a strategy to either develop material supply schedule or work more closely with material schedule, this is to mitigate materials shortages on site as this have adverse impact on project delivery.

Next to shortage of construction materials is Late order of construction materials with an MS =3.61. This factor has a moderate impact on the procurement strategy to be selected in relation to materials availability and supply on site. Late ordering implies late delivery.

Project and site managers must be proactive regarding the availability of materials on site. The strategy of inventory taking must be adopted and should be regular, this may be weekly or bi-weekly to ascertain materials level stock on site. This may be the influence of its rating as the third most influencing factors to be considered in the selection of procurement strategy for materials availability on site.

The factor with the least rating is Unsuitable location for material storage on site with an MS = 1.37. This factor applies mostly to congested, long and thin sites. It indicates the kind of construction to employ whether prefabricated materials, it incures double handling and damages during transportation of materials from one point to another.

Next to an unsuitable location for material is storage is Late delivery of construction materials. Arguably, this factor is rated as the second least factor to be considered on the construction materials related factors. The late delivery of materials on site leads to no productivity on site and ultimately may result in late delivery of the project. At various stages if project lags behind, it secures penalties, affects the competitive advantage and cause a bad reputation. Based on the above, it is important to evolve strategy or strategies that will mitigate late delivery of materials to site. These include early ordering and upfront purchase to mitigate increase in cost and late delivery.

5 DISCUSSIONS

The design and construction material related factors in construction significantly influence the selection of the contract procurement method. The procurement method chosen will depend on various aspects of the project. The design team characteristics such as skill, experience, communication, collaboration, innovation and procurement are key factors that influence procurement methods. This finding is in concordance with findings of Hu and Skibniewski (2022) on a study titled "The impact of the design team characteristics on the sustainable building construction cost: structural equation model analysis" and concluded that design team skill and experience are the most influential and determining factor that drives procurement and construction cost. Regarding the construction materials influencing the selection of procurement methods, this study finds that wastage of construction materials by workers and shortage of materials are the most influential factors for consideration in the selection of contract procurement method. These findings align with Sila and Gakabo (2021) and Rahman *et al* (2017) on wastage of construction materials by workers and shortage of construction materials respectively as factors most influencing the selection of contract procurement methods.

6 CONCLUSIONS

From the study findings the following conclusions are reached. For the design related factors, design team experience, project design complexity, mistakes in producing design documents are amongst the design related factors most influencing the selection of a contract procurement strategy in relation to project delivery. For the construction material related factors, wastage of construction materials by workers, shortage of construction materials, late order of construction materials are the construction material related factors that most influence the selection of a contract procurement strategy in project delivery.

It is recommended that design team experience, project design complexity, mistakes in producing design documents, wastage and shortage of construction materials should be the foremost factors that should be considered in the selection of a procurement strategy relative to project delivery.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Challenges of sustainable procurement practices in Northern Ghana

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ABSTRACT: Sustainable procurement is essential as it ensures organisations consider environmental, social, and economic impacts when acquiring materials, goods, and services from project inception to completion. Many studies have explored sustainability issues in the construction industry. However, few have investigated the challenges of sustainable procurement. This paper aims to assess the challenges of sustainable procurement practices in Northern Ghana. A survey conducted among fifty (50) construction professionals with in-depth knowledge of sustainable procurement revealed that political interference, lack of knowledge and awareness, and high cost of sustainable procurement are the main challenges hindering the implementation of sustainable procurement in Northern Ghana. The study further recommended enforcement of sustainable procurement policies and laws, promoting independence of procurement entities, and subsidising sustainable materials as mitigation strategies for implementing sustainable procurement. This paper enables project managers and policymakers to efficiently and effectively implement strategies to improve sustainable project delivery in the construction industry.

Keywords: Challenges, Strategies, Public procurement, Sustainable procurement, Northern Ghana

1 INTRODUCTION

Public procurement is widely acknowledged as the tool for implementing broader economic, social, and environmental transformation policies by various governments. Sustainable procurement has become the agenda of many organisations across developed and developing countries (Chari and Chiriseri 2014). However, many developing nations are currently in the initial stages of adopting sustainable procurement in public construction organisations. Mensah *et al.* (2014) stated that the construction sector has not focused much on the environmental, social, and economic impact of public procurement for the past decade.

Traditionally, procurement in the construction sector has mostly prioritised the lowest-rated bidder while disregarding the requirement to consider sustainability (Komolafe 2022). However, the ever-changing market conditions require that every organisation must innovate in providing services while ensuring they satisfy established sustainability requirements due to the dynamic market and intense competition.

Construction procurement refers to acquiring goods and services for construction projects based on established standards (Agyekum *et al.* 2023). Traditional construction procurement

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practices have been criticised for neglecting the societal, environmental and life cycle costs of projects and not adhering to existing procedures and policy regulations. Transparency International (2016) reported that corrupt activities in Africa cost over $148 billion annually. A study by the World Bank (2014) revealed that 50% to 70% of Ghana's budget is dedicated to procurement activities. Ottou *et al.* (2021) discovered that corruption in public procurement in Ghana results from the behaviours of the stakeholders involved in supervising procurement activities in the country.

The Ghanaian government has recently prioritised adopting and implementing sustainable procurement in publicly funded projects. Sustainable procurement in the construction industry helps reduce environmental damage and support social equality and economic growth while also contributing to the broader sustainable development goals (Meehan and Bryde 2015). Mensah and Ameyaw (2012) define sustainable procurement as the process of obtaining goods, works, and services while taking into account the environmental, social, economic, and safety factors to minimise any potential negative impacts and ensure value for money. Sustainable procurement aims to achieve value for money by considering environmental, social, and economic issues throughout the project life cycle, unlike conventional procurement, which focuses only on value for money.

Although sustainable procurement has been embraced by numerous nations and organisations, the majority of institutions in Northern Ghana have yet to completely implement sustainable procurement as part of their organisational culture (Etse *et al.* 2022). Therefore, this study offers a comprehensive analysis of the challenges and recommends strategies to improve the adoption and implementation of sustainable procurement practices in Northern Ghana. The study seeks to address this objective by:

Identifying the challenges faced in adopting and implementing sustainable procurement.

This study enhances understanding of sustainable procurement procedures by highlighting the drivers of sustainable procurement, the challenges encountered in adopting sustainable procurement and proposed strategies to address these challenges in Northern Ghana. This will help public and private sector organisations incorporate sustainability criteria into their procurement procedures and processes and overcome the challenges that impede their implementation.

2 LITERATURE REVIEW

2.1 *Overview of the public procurement system in Ghana*

The Public Procurement Act 2016 (Act 663) of Ghana defines procurement as the process of acquiring optimum goods and services of the highest quality, in the right quantities and at the appropriate times and locations to benefit the entire community. The public procurement processes and procedures ensure that firms or organisations purchase goods and services while prioritising sustainability, which is essential for any use of public funds. The procurement process is comprehensive and begins with adequate planning, effective budget allocation, inviting bids from other organisations, evaluating the bids, and awarding the contract to a competent contractor (Agbesi *et al.* 2018). The process involves efficient contract administration, performance evaluation, thorough monitoring and evaluation, auditing, and detailed reporting.

Public procurement has received attention recently because of the significant level of corruption that occurs throughout the provision of services in the public sector. According to Agbesi *et al.*(2018), public procurement significantly contributes to government corruption and a common source of public dishonesty in Ghana. Lember *et al.* (2013) state that public procurement is recognised as a valuable instrument for government policies and a foundation for promoting broader economic, environmental and social transformations.

Therefore, it is necessary to conduct various studies to increase sustainability awareness in developing countries, as the importance of integrating sustainability into public procurement processes is growing and becoming more significant worldwide (Adebayo 2015). Nations need to prioritise establishing sustainable public procurement systems that incorporate environmental and social benefits rather than solely focusing on the economic advantages of procurement. The Public Procurement Law in Ghana is being revised to incorporate a well-defined sustainable procurement element (Agyekum *et al.* 2023).

2.2 *Sustainable procurement practices in the construction industry*

Sustainable procurement applies sustainable development principles to the procurement process and procedures to help create a habitable planet and improve the quality of life of individuals. Erdiaw-Kwasie *et al.*(2023) defined sustainable procurement as maintaining social and ethical responsibility in purchasing, reducing environmental harm in the supply chain, and providing economically viable solutions that uphold the ethics of the construction industry. According to Uyarra and Flanagan (2010) the nature of sustainable procurement varies significantly between public and private entities.

Sustainable procurement in construction entails implementing development and design standards that provide cost-effective solutions, support social and economic growth, and reduce environmental damage (Agbesi *et al.* 2018). Implementing sustainability principles in procurement enhances efficiencies, lowers costs, and provides a competitive edge for businesses as society increasingly adopts this approach (Davila *et al.* 2003).

Countries need to transition their public procurement processes from solely focusing on economic advantages to implementing Sustainable procurement systems that yield lasting benefits for all individuals rather than simply for governmental entities. Sustainable procurement seeks to minimise the impact of the procured goods, works, and services throughout the whole lifecycle in the supply chain: maximise usage of resources through improved purchasing, materials recycling and re-use and efficient supply product lines (McMurray *et al.* 2014). Furthermore, implementing sustainable procurement practices fosters innovation and ensures that the supply chain meets social and environmental standards (Johnsen *et al.* 2018). Other benefits of sustainable procurement include waste reduction and cost savings from the purchase of goods and services (Singh and Chan 2022).

According to Asare & Prempeh (2017) poor production and consumption methods have led to environmental degradation, deteriorated climate conditions, and extreme poverty in many African countries. Sustainable procurement practices consider the environmental, social and economic aspects of the procurement procedures. It confirms policies that guarantee accessible, equitable, and open services to suppliers and society, as well as benefits for the long-term economy while ensuring accountability.

Despite sustainable procurement being the viable choice for the future, it has been neglected by the institutions in charge of executing public funded projects in Northern Ghana. The unwillingness and lack of interest of contractors to adopt and use sustainable procurement in the execution of projects posed a challenge to sustainable development (Osei-Tutu *et al.* 2014). Transformative efforts have been made by organisations across sectors to address the challenges and encourage the adoption and implementation of sustainable procurement practices.

2.3 *Dimensions of sustainable procurement*

Sustainable procurement is understood by the integration of economic, social, and environmental components of sustainability (Islam and Siwar 2013). Willard (2012) asserts that meeting all of these criteria is essential for achieving sustainable procurement. Procurement processes have to consider factors beyond quality, price, and performance when making decisions. Some of the issues to be integrated under the Triple bottom line in the procurement procedures and processes are shown in Figure 1 below:

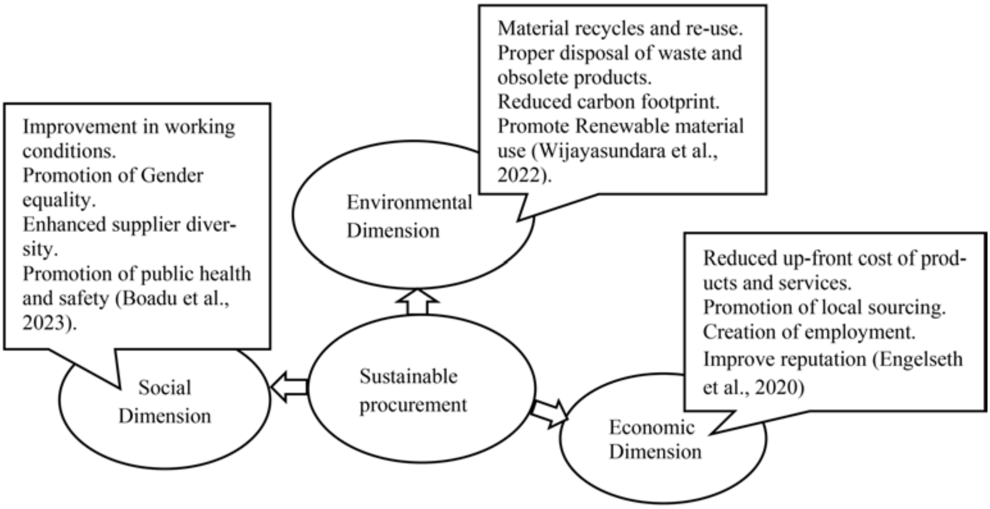

Figure 1. Summary of sustainability dimensions of sustainable procurement.

2.4 *Drivers of sustainable procurement*

Efforts are currently being made to include sustainable procurement principles in the construction industry throughout the entire process of the project development (Bohari *et al.* 2017). Susanty *et al.* (2019) postulate that procurement processes have become an area of great concern in many organisations.

The adoption and implementation of sustainable procurement could be driven by either internal or external factors. Literature has identified increasing awareness and financial benefits as the primary drivers of sustainable procurement (Bohari *et al.* 2017; Susanty *et al.* 2019). Financial benefits can be obtained through the use of energy-efficient materials, waste reduction, and the recycling of outdated products. Dobers & Wolff (2000) suggested client acceptability and the increased focus on supply chains by corporate clients to advance sustainability objectives as drivers of sustainable procurement.

The commitment of top management to sustainable practices in public procurement is another key factor that drives the adoption and implementation of sustainable procurement (Al Nuaimi *et al.* 2020). According to Wijethilake and Lama (2019) top management plays a crucial role in influencing sustainable practices due to their responsibility for the organisation's activities and involvement in its operations. Their support is linked to the introduction, adoption, and implementation of sustainable procurement. Bamgbade *et al.* (2018) postulated that the application of sustainable practices by large-scale organisations is significant but negatively correlated with government support. However, a favourable policy environment is crucial for the adoption and implementation of sustainable procurement by large companies.

A study by Ryu and Sueyoshi (2021) discovered access to financial and technological resources as key drives of long-term sustainable procurement adoption in developing countries. Additionally, more environmentally labelled products, standardised criteria, increased managerial attention, and increased teamwork were emphasised as critical drivers (Chari and Chiriseri 2014). Furthermore, a study by Ogunsanya *et al.* (2022) identified investment in innovation and technology, compliance with regulations, investment in education and willingness of governments as sustainable procurement drivers.

2.5 *Challenges to the implementation of sustainable procurement*

Despite the enthusiasm for sustainable development in Africa, sustainable procurement practices have not yet been widely adopted and implemented in the construction industry. Several challenges have hindered companies from integrating sustainability into their procurement processes and practices. A study by Ameyaw *et al.* (2012) discovered that a lack of technical and management capacity, training and education, and inadequate research and innovation on sustainable procurement are the major barriers to implementing sustainable procurement in Ghana. Fitriani and Ajayi (2023) opined that lack of awareness and high cost associated with sustainable procurement are the main challenges hindering the implementation. Masoud (2023) discovered in a study that political interference negatively influences procurement processes and performance in Tanzania. Chari & Chiriseri (2014) identified lack of information, emphasis on monetary considerations and focus on current product performance without long-term sustainability as challenges to sustainable procurement.

Also, project clients may be reluctant to implement sustainable procurement practices because of the substantial risk associated with inexperienced approaches, budgetary constraints, and poor policy regulations (Nelms *et al.* 2005; Tumpa *et al.* 2019). Furthermore, the absence of support from senior management has been identified as a significant obstacle to achieving sustainable procurement (Fitriani and Ajayi 2023). Sustainable sourcing necessitates the initial dedication and commitment of senior management in an organisation and the active involvement of all stakeholders in sustainability procedures (Formentini and Taticchi 2016).

In Ghana, limited studies have been conducted to assess the implementation of sustainable procurement despite its incorporation in the revised Act 663 of 2003 in 2016 (Act 914). This study intends to analyse the challenges faced and recommend strategies to improve the adoption and implementation of sustainable procurement in Northern Ghana.

3 METHODOLOGY

Kothari (2017) defines research methodology as a systematic approach or process used to accomplish research aims and objectives. It entails determining the result of a specific study subject in a given situation. An in-depth review of literature was carried out to determine the factors influencing sustainable procurement, including drivers, challenges, and other relevant variables. Quantitative data was obtained from professionals using questionnaires as the data collection instrument. The questionnaire contains only closed-ended scaled response questions using a five-point Likert scale that ranges from 'Strongly Disagree = 1' to 'Strongly Agree = 5' to gather respondents' opinions on the variables.

Though many procurement professionals exist in the construction industry within Northern Ghana, finding those with in-depth knowledge about the specific topic being studied was difficult. Participants were selected for the study via purposive sampling and recommendations through the snowball approach. Parker *et al.* (2019) suggested that purposive and snowball sampling methods are suitable when the population for a study is unknown. Hence, the sample size for this study was determined after data collection to be fifty (50). Since reliable information about population locations and numbers is not available. Mooi *et al.* (2018) emphasised that the strength of samples lies in precise selection rather than their sizes. Fifty (50) procurement professionals of public procurement and construction entities with in-depth knowledge and experience in sustainable procurement in Northern Ghana were surveyed.

The data from the survey was analysed by employing descriptive statistics and the Relative Importance Index (RII), which is calculated as

$$RII = \frac{\sum W}{(A \times N)} \tag{1}$$

where W is the weight assigned to each factor by the respondents on a scale of 1 to 5, N is the total number of respondents, and A is the highest response value (5 in this instance). The Cronbach's Alpha Coefficient test was utilised to evaluate the reliability and consistency of the scale and variables.

4 RESULTS AND DISCUSSION

The analysis showed that 55% of the respondents were procurement officers, 35% were project managers, and 10% were project engineers. Most of the respondents (64%) were master's degree holders, 29.5% were bachelor's degree holders, and 6.5% were PhD holders. Furthermore, over half of the participants had more than ten (10) years of work experience, indicating that they possess sufficient knowledge to offer valuable information for the study.

The Cronbach's Alpha Test was performed to evaluate the internal consistency of the scale used to rate the various variables. Bonett and Wright (2015) state that a score of 0.70 or above suggests that the rating scale used is reliable and internally consistent. The Cronbach's Alpha Coefficient value of 0.996 from Table 1 indicates a high level of reliability in the Likert scale used to measure the challenges.

Table 2 indicates the challenges faced in the implementation of sustainable procurement practices.

Table 1. Reliability statistics.

	Items Number	Cronbach's Alpha Coefficient
Variables	13	0.996

Table 2. Challenges faced in the implementation of sustainable procurement practices.

SN	Challenges	Mean	St. Error Mean	Std. Deviation	Skewness	RII	Rankings
1	Political interference in the procurement processes	3.98	.337	1.253	−1.256	0.796	1ST
2	Lack of knowledge and awareness	3.90	.337	1.233	−1.095	0.780	2ND
3	High cost of sustainable procurement	3.74	.337	1.103	−.786	0.748	3RD
4	Lack of punitive actions for flouters of sustainable policies	3.70	.337	1.093	−.733	0.740	4TH
5	Absence of internal management structures	3.68	.337	1.186	−.794	0.736	5TH
6	Lack of support from top management	3.66	.337	1.239	−.719	0.732	8TH
7	Inadequate research and innovation on sustainable procurement	3.66	.337	1.171	−.721	0.732	6TH
8	Inadequate resources to integrate sustainability factors in procurement practice	3.66	.337	1.206	−.684	0.732	7TH
9	Lack of capacity of small-scale suppliers/ contractors	3.60	.337	1.245	−.700	0.720	9TH
10	Budgetary constraints	3.58	.337	1.214	−.765	0.716	10TH
11	Lack of technical and management capacity	3.52	.337	1.282	−.773	0.704	12TH
12	Inadequate enforcement of the Public Procurement laws	3.52	.337	1.147	−.811	0.704	11TH
13	Poor remuneration for procurement officers	3.50	.337	1.216	−.567	0.700	13TH

Std = standard deviation, RII = Relative Importance Index.

The variables in Table 2. were ranked according to their relative importance index (RII) values, and in a situation where two or more variables have the same RII value, the variable with the lowest standard deviation was assigned a higher ranking (Ahadzie 2007). According to Ahadzie *et al.*(2008) the standard error is the standard deviation of the sample means and serves as an indicator of how accurately a sample reflects the population. The standard error for all the means is relatively close to zero, indicating that the sample selected is an accurate reflection of the population (Ahadzie *et al.* 2008). From the analysis, political interference in the procurement processes was ranked first with an RII value of 0.796. This implies that political interference negatively affects the implementation and performance of sustainable procurement in Northern Ghana. Lack of knowledge and awareness was ranked second with an RII value of 0.780. This deficiency is often manifested as a result of the failure of organizations to prioritize sustainability considerations when sourcing goods and services, resulting in negative impacts on the environment, society and the long-term business sustainability of the company.

Also, high cost of procurement was ranked third with an RII value of 0.748. This confirms the findings of Fitriani and Ajayi (2023) that sustainable procurement requires substantial of amount resources and capital for effective implementation. Lack of punitive actions for flouters of sustainable policies, absence of internal management structures and inadequate research and innovation on sustainable procurement were ranked fourth, fifth and sixth with an RII of 0.740, 0.736 and 0.732, respectively. The absence of penalties imposed on organizations that fail to adhere to established sustainability standards often leads to disregard of these standards, which hinders the implementation of sustainable procurement. According to Giunipero *et al.*(2012) lack of well-defined systems and frameworks for managing internal operations, processes, and resources often hinders the successful implementation of sustainable procurement practices within organizations.

Also, Inadequate resources to integrate sustainability factors in procurement practice and lack of support from top management were ranked seventh and eighth with an RII of 0.732 and standard deviation values of 1.206 and 1.239, respectively. Furthermore, lack of capacity of small-scale suppliers/contractors and budgetary constraints were ranked ninth and tenth with an RII of 0.720 and 0.716, respectively. Inadequate enforcement of the Public Procurement laws and lack of technical and management capacity were ranked eleventh and twelfth with the same RII value of 0.704 and a standard deviation value of 1.147 and 1.282, respectively. Lastly, Limited motivation for procurement officers was ranked thirteenth with an RII of 0.700.

Orcan (2020) suggested that data normality testing can be done using univariate skewness in a study. Based on the data in Table 2. all variables showed a leftward skew, indicated by negative skewness. However, according to Orcan (2020) data is considered normalised when the absolute value of skewness is less than 3, which was confirmed in this investigation.

5 CONCLUSIONS

The study provided a broad overview of the Ghanaian procurement system to ascertain the extent of the integration of sustainability practices into the public procurement system. It was revealed that the construction industry in Northern Ghana has not yet fully embraced sustainability in its procurement processes and procedures despite the inclusion of sustainable procurement in the revision of Act 663 of 2003 in 2016 (Act 914). Most institutions in charge of executing public funded projects in Northern Ghana have not fully implemented sustainable procurement which has been an issue of great concern. Therefore, it is imperative to establish broader collaboration and involvement among many stakeholders in the construction industry's supply chain, including the government, private developers, construction professionals, contractors, and suppliers to foster the implementation of sustainable procurement.

The findings indicated that political interference in the procurement processes, lack of knowledge and awareness, and high cost of sustainable procurement are the main challenges affecting the adoption and implementation of sustainable procurement in Northern Ghana.

Hence, there is a need for the government to enforce sustainable procurement policies and laws. Also, it is crucial for government and professional bodies within the construction industry to actively educate and raise awareness on the long-term financial benefits of sustainable procurement in order to facilitate the efficient implementation of sustainable procurement. It is again necessary to promote the independence of procurement entities, subsidise sustainable materials and provide professional development in sustainable procurement within the construction industry in Northern Ghana.

Lastly, procurement entities should implement post-procurement reviews to ensure that all procurement processes integrate sustainable practices into existing practices. This would enable project stakeholders and policymakers to efficiently and effectively implement the practice of sustainable procurement. Future research could be conducted to assess the effectiveness of the provisions in the Procurement Act 914 of 2016 in addressing sustainability issues in the public sector.

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Theme 6: Cost management & infrastructure planning

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Adoption of lean construction in project design management in Zimbabwe

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ABSTRACT: This study investigates the level of implementation of lean construction in design management of construction projects in Zimbabwe. Through a survey design, 50 questionnaires were distributed to contractors, engineers, quantity surveyors, architects, and project managers to gather data on the implementation of lean construction in project design management. Through statistical analysis, the findings revealed that lean construction has been adopted to a lesser extent in project design management. Drawing from the findings, the study concludes that lean construction has been lowly adopted in project design management leading to waste of materials, labour, and value of projects. Hence, this study recommends that clients introduce and enforce the integration of lean construction principles into the design process. The results of the study are instrumental in informing construction projects' policy reforms aimed at reducing construction costs. However, the results cannot be generalised to all jurisdictions due to contextual differences.

Keywords: Lean Construction, Design management, Sustainable construction, Zimbabwean context

1 INTRODUCTION

Globally, the adoption of lean principles in construction is gradually increasing, though in some nations it is very low. Research has shown that the adoption of lean principles remains very low in the United Kingdom (Oyedemi and Udechukwu 2023). In the United States of America, lean construction has been adopted though there is marginal use of the techniques among contractors (Ghosh and Burghart 2021). Babalola, Ibem and Ezema (2019) posit that lean construction has mostly been adopted to improve quality, cost and time performance and achieve client/end-user satisfaction. Research has been conducted to increase the uptake of lean construction by looking at barriers to its adoption (Balkhy *et al.* 2021; Moyo and Chigara 2023; Romo *et al.* 2024). However, as previously indicated, the extent of adoption of lean in design management is still low.

There has been widespread recognition of the perceived benefits that can be experienced by adopting lean construction in project design on construction operations. According to

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Babalola, Ibem and Ezema (2019), lean construction can potentially enhance the project's achievement of economic, social, and ecological goals. In addition, the highly fragmented nature of the construction industry can be easily coordinated, necessitating the reduction in waste experienced by managing separate fragments (Hyarat *et al.* 2022). Construction industry has been found to perform poorly in sustainability and productivity facets (Hatema *et al.* 2022). This failure has largely been attributed to the project design management failures (Fosse and Ballard 2016). Various scholars (Balkhy *et al.* 2021; Herrera *et al.* 2020) show that the design process can be effectively managed by the application of lean principles. Few studies focusing on the application of lean principles in the integration of design and construction include Gambetese and Pestana (2014). Herrera *et al.* (2020) indicates that the use of lean construction in design is still at infancy levels. Design stage is very crucial in construction works as it subsequently affects all succeeding project stages (Fosse and Ballard 2016). Design changes to the concept are earmarked to enhance efficiency as part of the lean production philosophy. Therefore, any waste minimisation effort should commence in the design stage for effective achievement of the perceived benefits from lean construction.

Lean construction has been adopted at varying levels in Africa (Mangaroo-Pillay and Coetze 2020; Monyane *et al.* 2020). These authors show low adoption of lean construction within the South African context. Low adoption of Lean construction in South Africa is attributed to the incorrect implementation methodologies, and policy and cultural barriers. In Egypt, Shaqour (2022) seems to acknowledge an improved adoption level of lean construction which had successfully mitigated against time-related risks. Mangaroo-Pillay and Coetzee (2020) further observed that only 10% of lean implementation ventures were successful. Furthermore, in Ghana, existing studies (Ankomah *et al.* 2020; Kpamma *et al.* 2017) confirm that lean construction adoption is low, just like her counterparts in the African continent.

In Zimbabwe, few studies on lean construction were undertaken, though its use in design management on construction projects is not known. Moyo and Chigara (2023) highlight the barriers to lean construction in Zimbabwe and advocated for increased government support and promulgated of policies that support the implementation of lean construction. Moyo and Emuze (2023) also conducted a conceptual study on the use of theory of constraints to build a lean house to enhance construction operations in Zimbabwe. Maware and Adetunji (2019) explored the use of lean in the manufacturing operations and found out an improvement in the quality of products, designs, flow and communication. These few studies that were undertaken In Zimbabwe did not address the dynamics involving the adoption of lean construction in project design management. This gap has thus prompted the study on the level of adoption of lean construction as a tool in alleviating inefficiencies experienced during project design management in this context. The paper provides an overview of the literature review including the adopted study methodology and empirical insights on the level of adoption of lean construction.

2 LEAN CONSTRUCTION

Oladokun and Alshaikh (2018) posit that project objectives have become very difficult to achieve due to ever-increasing project complexity, new procurement methods, and globalisation. Lean construction has been adopted to address the mentioned inefficiencies (Chaize *et al.* 2022). However, the adoption of lean construction should be initiated and enforced by clients since they are the initiators and sponsors of construction projects (Ahmed, Hossain, and Haq 2020). Clients possess the capacity to exert pressure on consultants and contractors to adopt lean.

2.1 *The lean concept*

The lean concept is a production philosophy that focuses on the maximisation of value through the minimisation of all waste forms such as overproduction, delays, excess motion, excess transportation, overprocessing, inventory, defects, and unused skill/talent (Dhaarini and Chitra 2020). Its primary objective in the construction industry is to improve the construction processes to enable the achievement of client needs (Monyane *et al.* 2018; Morshidi *et al.* 2022). Lean construction emanated from the Toyota Production System (TPS) (Fritze 2016). As noted by Fritze, TPS is a production philosophy aimed at improving profits through eliminating waste, continuous improvement of the processes, Just-in-Time inventory management, and automation. This production philosophy ushered in new management thinking into the construction industry focusing on improving the production line, reduction of waste, value addition production, and efficiency (Nikakhtar *et al.* 2015). Lean principles in construction introduce the conservation of resources, particularly in the design stage. The stage involves the conceptualisation of the client's needs into specialised designs and inefficiencies in this stage culminate in the waste of resources through reworks.

2.2 *Lean tools*

Different lean tools have been applied to construction projects in the enhancement of design management. These include Integrated Project Delivery (IPD), Last Planner System (LPS), Target Value Design (TVD), Building Information Modelling (BIM), Value Stream Mapping (VSM), Key Performance Indicators (KPI) and Six Sigma (Chaize *et al.* 2022). IPD objective is to counter the high degree of misunderstanding and hostility that usually emanates from the fragmentation of the construction industry. Thus, IPD plays a key role in enhancing design management by eliminating adversity among the stakeholders on construction contracts, thus giving room to innovation thereby achieving the project goals. On the other hand, LPS is an additional lean construction tool that can be utilised in design management (Cwik and Roslon 2017). According to Cwik and Roslon (2017), the system allows easy identification of obstacles by breaking down the project's tasks into detailed milestones and assigning leaders to each milestone termed the last planners. This proactive approach allows early identification and minimisation of variation through corrective and preventive measures that minimise waste.

A plethora of studies (Gimenez *et al.* 2022; Orihuelaa *et al.* 2015) contend that a detailed and comprehensive estimate that is set below the market price generates maximum value for the client by adopting a lean construction tool named TDV. These authors argue that estimates of this nature improve teamwork through collaborated inputs from all project participants fostering efficient problem identification and solving thereby eliminating all forms of waste. Thus, the main objective of TVD is to make the client's requirements the focus of design. Furthermore, lean construction is also attained by implementing BIM which facilitates easier collaboration between participants and improves efficiency and workflow (Eldeep *et al.* 2022). The design stage is prone to several challenges due to the general complexities associated with the activity. Thus, Eldeep, Farag and Hafez (2022) assert that BIM enhances faster project delivery through early problem-solving, risk management, conflict management, waste minimisation, and improved productivity. Minimisation of waste in lean construction has also been attributable to the application of VSM (Barathwaj *et al.* 2017). As noted by Barathwaj, Singh and Gunarani (2017), VSM categorises the process activities into value-adding (VA) and Non-Value Adding (NVA) activities. This enables the reduction of the high percentage of non-value-adding and time-wasting activities during each construction stage (Gunduz and Naser 2019).

KPIs have been recognised as one of the lean construction tools capable of steering the whole project team towards the same project goals (Monyane *et al.* 2017) resulting in efficient use of resources is established. Proper identification of KPIs has been attested to eliminate waste generation and increase value (Hristov and Chirico 2019).

Lastly, lean principles can be applied in construction by adopting Six Sigma. Six Sigma can be applied at any stage of the project cycle to identify and prevent reworks and defects (Linde and Philippov 2020). Accordingly, Six Sigma integrates financial and statistical analysis with project management methodologies to achieve improved project flow and better quality through the identification and rectification of mistakes in existing processes (Plenert and Plenert 2018). The tool relies on the application of tools, collaborative teamwork, clear-cut project objectives, and periodic project reviews (Siddiqui *et al.* 2016).

2.3 *Adoption of lean tools in project design management*

The introduction of Lean in design management has proven to be a game changer in achieving the critical project objectives (Ahmed *et al.* 2020). Its adoption has faced several hurdles in both developed and developing countries (Hyarat *et al.* 2022). Obstacles such as lack of lean skills and knowledge, unique, dynamic, fragmented and dissolved nature of construction and lack of a universal recognised lean benchmarking criterion have been cited in extant literature (Anuar and Ng 2014; Ahmed *et al.* 2021).

The use of lean principles in design management has been explored with varying rates of success. Gambetese and Pestana (2014) point out that the significant impact of lean principles in worker safety is experienced during the construction stage, insinuating that there is a reduced need for the application of lean principles during the design stage. Though optimum production costs and good buildability were found to be anchor management goals in project design based on a lean construction philosophy (Herrera *et al.* 2020). Herrera and colleagues found out that the application of lean principles in design is still at the initial levels of implementation. Therefore, there is a need to explore the levels of adoption of lean construction in design management as a way of managing potential sources of waste from the design stage to ensure that maximum potential benefits are experienced on projects.

3 RESEARCH METHODOLOGY

This study adopted a cross-sectional survey design. The approach enabled the systematic collection and analysis of numerical data (Bryman 2016). Through a self-administered web-based questionnaire survey, quantitative data were collected from 50 respondents based in Harare and Bulawayo to determine the level of adoption of lean tools and techniques in design management on construction projects in Zimbabwe. The study confined to Harare and Bulawayo because these are two major cities with high economic activities within the Zimbabwean context. Moreover, approximately 80% of the consultants and contractors are headquartered in Harare and Bulawayo (CIFOZ 2024). The self-administered surveys provided respondents with the privacy to provide candid responses, thereby minimising social desirability bias and enhancing the reliability of the data collected (Fowler 2013). The quantitative method facilitated the measurement of variables related to lean practices. The respondents were randomly drawn from quantity surveyors, engineers, architects, and contractors registered with the Zimbabwe Institute of Quantity Surveyors (ZIQS), Zimbabwe Association of Consulting Engineers (ZACE), Institute of Architects of Zimbabwe (IAZ) and Construction Industry Federation of Zimbabwe (CIFOZ) in category A B and C respectively. The selected respondents were appropriate for the study since they are responsible for design management and ultimately responsible for the implementation of lean principles throughout the construction cycle. Additionally, the diverse respondents facilitated a comprehensive understanding of the subject matter, thereby enhancing the validity and applicability of the research findings (Babbie 2020). Table 1 shows the study's sample profile. The collected data were tabulated and analysed using mean scores to assess the level of usage of the selected lean tools in the Zimbabwean construction. The Statistical Package for Social Science (SPSS) version 24 (with 95% confidence in the results) aided in generating mean rating of the data.

Table 1. The study's sample profile.

Population Category	Sample Size
Quantity Surveyors	10
Project Managers	10
Engineers	10
Architects	10
Contractors	10
TOTAL	50

4 RESULTS

4.1 *Response rate*

A total of 50 questionnaires were distributed to selected respondents. From this distribution, 30 questionnaires were successfully returned by the respondents, constituting 60% response rate. This response rate is acceptable as alluded to by Grimmer and Bialocerkowski (2015). Additionally, the response rate of 60% surpasses the range proposed by Creswell (2014) who argue that online surveys generally range from 20% to 30%.

4.2 *Demographic information of respondents*

Table 2 presents the respondents' demographic information regarding highest educational qualification.

Table 2. Demographic information of participants.

Category		Frequency	Percentage
Educational qualification			
	National certificate	0	0
	Diploma	3	13
	Bachelor's Degree	0	0
	Honour's Degree	19	63
	Master' s Degree	8	24
	TOTAL	30	100

As shown in Table 2, most respondents possess honours' degrees (63%), followed by those with masters' degrees (24%) and lastly, holders of diplomas (13%). The level of education exhibited by the respondents demonstrates the potential of the respondents to fairly respond to the key questions presented in the data collection instrument.

4.3 *Level of adoption of lean construction*

The respondents were asked to rate the extent to which they adopt lean tools and techniques during design management on a likert scale of 1 to 5 with 1 (not adopted at all), 2 (low level of adoption), 3 (Medium level of adoption), 4 (high level of adoption), 5 (Advanced level of adoption). Table 3 indicates the mean ratings of the lean tools and techniques together with the standard deviations. The results measure the level of adoption of lean construction within Harare and Bulawayo.

From Table 3, the lower standard deviation indicates a narrower distribution which shows that the responses obtained for that technique are more similar and that a large number of

Table 3. Level of adoption of lean construction.

Lean Tool	Total (N)	Max	Mean	Std. Dev	Rank
Integrated Project Delivery Method	30	5	4.00	0.450	1
Key Performance Indicator	30	5	3.93	0.640	2
Target Value Design	30	4	2.70	0.995	3
Value Stream Mapping	30	5	2.30	0.031	4
Six Sigma	30	5	2.03	1.070	5
Building Information Modelling (BIM)	30	4	1.47	0.855	6
Last Planner System	30	3	1.40	0.924	7

respondents have the same view on the rating of the technique, hence vice versa. The results indicate that the integrated project delivery method was the most adopted tool with a mean of 4.00, which represents a high level of adoption. The key performance indicator was ranked second with a mean of 3.93, representing a medium level of adoption. Target Value Design, Value Stream Mapping, Six Sigma, BIM and Last Planner System were lowly rated with mean ratings of 2.70; 2.30; 2.03; 1.47 and 1.40 respectively. Table 3 also shows that the standard deviation for these lowly used lean tools is somewhat large portraying major dispersion of the data from the mean. Thus, based on the results, it appears that most of the lean tools are inadequately utilized and utilized in project design management to advance the sustainability of the construction industry within the Zimbabwean context. This could be attributed to several challenges as shown on the next paragraph.

The respondents were asked to rate the frequency of occurrence of a set of identified challenges in their efforts to adopt lean principles in project design management using a Likert scale of 1 to 5 with 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always). The challenges impeding the use of lean principles in design management were found to be a lack of skills and knowledge (4.63) resistance to innovation and technological advancement (4.57) lack of stakeholder support (4.57) lack of lean design management benchmarking (4.23) use of traditional procurement systems (4.13), fragmentation (3.23). Most of the results indicate that these challenges are experienced often except for fragmentation which is sometimes encountered.

5 DISCUSSION OF RESULTS

The results show a high adoption level for Integrated Project Delivery. IPD allows for collaboration of the consultant team and the various contractors before the commencement of the project thereby creating synergies necessary to yield project efficiency. Findings show a high level of corroboration with the views of (Gambetese and Pestana 2014).

Generally, the results indicate a very low adoption level of the five out of seven lean tools used for design management. This corroborates the results of several scholars (Hyarat *et al.* 2022; Mangaroo-Pillay and Coetzee 2020; Monyane *et al.* 2020) which indicate that lean construction techniques have been adopted at a low level. Low levels of adoption of lean principles in construction projects have also been witnessed in Ghana (Ankomah *et al.* 2020), and South Africa (Makondo and Chiromo 2020). Low adoption of lean principles in project design management indicates that pronounced wasteful behavior could be experienced on construction projects (Kpamma *et al.* 2017). This also shows that construction projects are failing to attain much-needed value for money for the client. Further, these wasted resources could have been spearheaded for other critical projects for the well-being of society.

Application of Lean principles in project design management is mostly impeded by lack of knowledge, resistance to innovation, lack of benchmarks in lean design, and use of Traditional procurement systems (TPS). The results confirm the findings of several studies

(Evans *et al.* 2023; Morshidi *et al.* 2022; Moyo and Chigara 2023) which mainly attribute the low adoption of lean construction techniques to lack of implementation knowledge. However, studies undertaken in Ghana and South Africa indicate that there is a good level of awareness of lean principles in construction (Ankomah *et al.* 2020; Makondo and Chiromo 2020). Lean philosophy is still new and developing and thus it becomes difficult to align the needs of the construction industry to lean principles due to the uniqueness, dynamic and fragmentation of the construction industry to disrupt the flow of lean (Harrison and Kinsman 2017). The study's results further corroborate the view of Anuar and Ng (2014) on the limitations imposed by the lack of standardised benchmarking criteria in enhancing the adoption of lean tools in project design management. Monyane *et al.*, (2020) acknowledge a low lean uptake in the last two decades attributing this to structural and cultural barriers militating against the successful adoption of lean construction. Further, the result of lean use in project design being impeded by lack of stakeholder cooperation also supports the opinions of Ahmed, Hossain and Haq (2021) who pointed out the lack of stakeholder support. Thus, the low adoption of lean construction in Zimbabwe is consistent with the situation in most developing countries, hence a cause of concern.

Therefore, the study has shown a low adoption of lean tools in project design management due to a lack of understanding, lack of stakeholder cooperation, use of TPS and resistance to change. These challenges share commonality with those in most African developing countries such as Ghana, South Africa and Egypt.

6 CONCLUSION

The significance of the design stage in construction projects can never be underrated. During this stage, the client's needs and requirements are conceptualised into different forms of specialised designs by the various professionals. Lean tools and techniques implemented during design management have a great potential of turning around the Zimbabwean construction industry through waste reduction and enhanced productivity. However, the adoption of lean construction techniques in project design management is still low as evidenced by the results of the study. Integrated Project Delivery and Key Performance Indicators are the predominant lean tools that seem to be adopted on Zimbabwean construction projects. Nonetheless, these techniques need to be augmented to harness the maximum benefits of lean and enhance design management if the Zimbabwean construction industry is to be sustained. Construction professionals seem to lack knowledge of the various lean tools that exist. The study therefore recommends clients to enforce the application of lean construction tools on construction projects as they are the initiators and sponsors of construction projects. The critical project decisions made by clients make them the best lean implementers. These client-related decisions include deciding on procurement routes, contracts and project team appointment, which are key and decisive factors that determine and aid the general level of lean implementation. Zimbabwean construction professionals need to be trained on the application of lean construction principles to enhance waste reduction on projects. Training is inevitable because lean implementation process is people-oriented. The results of this study could be influential in enlightening clients on measures of ensuring cost savings on construction projects by raising awareness on the aspects to incorporate during the design stage which culminates in waste reduction and cost effectiveness. However, the small sample size and the geographical delimitation employed preclude the results from being applied to all contexts without caution. Furthermore, the findings offer valuable insights to policymakers to develop policies that promote the adoption of lean tools in project design management for the sustainability of the Zimbabwean construction industry. The results of this study could also be useful to researchers, practitioners, clients, and construction companies in Zimbabwe to focus their attention and resources on the significant drivers to the successful adoption of LC in the design phase.

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Time overruns in South African construction projects: Unveiling challenges and solutions from a contractor's viewpoint

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ABSTRACT: This study aims to assess the impacts of time delays in construction projects in South Africa, focusing on contractors' perspectives. A mixed-methods approach was employed, utilizing semi-structured interviews and survey questionnaires designed based on the study's objectives. The acquired data was analyzed thematically for qualitative insights and descriptively for quantitative data. The findings reveal that improved project management practices, better financial strategies, increased technological adoption, and stronger regulatory reforms are effective in significantly reducing time overruns in construction projects. This study contributes to the existing body of knowledge by providing a comprehensive analysis of approaches to address time overruns from contractors' perspectives, emphasizing the effectiveness of various strategies. The results highlight the importance of adopting improved project management and financial strategies, embracing technology, and implementing regulatory reforms to reduce delays in construction projects in South Africa.

Keywords: Contractors, construction projects, project delays, time overruns

1 INTRODUCTION

The construction sector in South Africa, like many others globally, is burdened by the issue of time overruns, which have a substantial effect on project expenses, stakeholder contentment, and total project achievement. The extent and severity of construction time overruns in South Africa provide substantial difficulties to the industry, characterized by their extensive influence on project delivery, time escalation, and stakeholder satisfaction Tshidavhu (2019). The country's distinct socio-economic and environmental conditions worsen these problems, including labor strikes, lack of skilled workers, and unpredictable material expenses, which are further complicated by legislative obstacles and bureaucratic inefficiency. Moreover, the intricate socio-political environment in South Africa has a significant impact on public infrastructure initiatives since any delays might have extensive repercussions on both economic progress and social fairness (Olsonoski and Gianoli 2024).

Construction timeframes are typically affected by environmental considerations, including the country's diverse climate and biodiversity. These factors might lead to delays in projects owing to unexpected environmental limitations or the need to adhere to environmental protection legislation. The presence of these factors, along with the pressures of urbanization and the requirement for sustainable development practices, emphasize the crucial importance of dealing with delays in South Africa's construction industry (Mathobela *et al.* 2024). The research aims to address the significant problem of project delays in the South African construction sector by examining and offering practical solutions from the contractors' point of view. The goal is to improve project efficiency and economic feasibility. The paper begins with an overview of the challenges faced by the construction industry, followed by the

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research objectives. It then outlines the research methodology, presents the key findings, discusses the implications for practice, and concludes with recommendations for future research. The next sections include a comprehensive literature review on time overruns in the construction industry globally, a detailed explanation of the research methods used, the findings and discussions, and the conclusion.

2 OVERVIEW OF TIME OVERRUNS IN THE CONSTRUCTION INDUSTRY

The construction industry is crucial to the country's economy as it spearheads infrastructure development and generates job opportunities in several areas (Lopes 2012). Although confronted with obstacles like as economic volatility, labor conflicts, and project setbacks, the sector demonstrates resilience by consistently adjusting via cutting-edge technology and sustainable methods to fulfil the increasing need for infrastructure and housing. Internationally, the primary causes of delays in construction projects frequently arise from unpredictable elements such as inclement weather, disruptions in the supply chain, and unforeseen site-related complications, in addition to more manageable factors like subpar project management, insufficient planning, and alterations in project scope (Nikjow *et al.* 2021). These issues not only cause project timetables to be delayed but also increase expenses and put pressure on relationships among stakeholders. This emphasizes the intricate and linked nature of managing construction projects on a worldwide level. The statistical data from the South African construction industry indicates a worrisome pattern of projects taking longer than planned, especially in public sector infrastructure. Many projects are beyond their initial timelines by substantial amounts. This pattern exemplifies wider difficulties in the sector, such as regulatory obstacles, budgetary limitations, and logistical problems, which affect the prompt completion of projects and emphasize the need for enhanced project management and strategic planning.

Time overruns in construction refer to the prolongation of a construction project beyond its scheduled completion date (Mukuka *et al.* 2015). These delays may be caused by several causes such as insufficient planning, unexpected site circumstances, problems with the supply chain, and unfavourable weather conditions, among others. The importance of these overruns is significant since they affect projects by increasing expenses, perhaps causing legal and contractual issues, damaging the image of the businesses involved, and having negative economic impacts on a larger scale (Salunkhe and Patil 2014). Furthermore, exceeding the allocated time for a project might jeopardize the overall quality of the project, put a strain on relationships with stakeholders, and cause delays in realizing the anticipated project advantages (Kerzner 2017). It is crucial to use good project management strategies to identify and reduce the risks associated with time overruns to achieve project success and minimize their negative impacts.

Time overruns in construction projects can have severe and complex impacts, affecting not only the financial health of the projects but also their overall success and sustainability. According to recent studies by Thompson and Chan (2023), the financial implications of time overruns are profound, with projects often experiencing substantial cost escalations that can undermine their economic viability. Moreover, Liu *et al.* (2024) highlight that beyond the immediate financial costs, time overruns can lead to a cascade of negative outcomes including legal disputes, strained relationships with stakeholders, and reputational damage for construction firms. This is particularly critical in competitive markets where reputation and trust are paramount for securing future projects. Furthermore, Johnson and Smith (2023) emphasize the social and environmental consequences of delayed construction projects, including increased carbon footprints and disruption to local communities.

Recent studies indicate that time overruns in South African construction projects remain a significant challenge, with more than 50% of public sector projects experiencing delays of over six months (CIDB 2022). A notable case study is the construction of the Kusile Power Station, which has been plagued by delays and budget overruns, exemplifying the systemic issues within the industry (Eskom 2023). These delays are often attributed to inadequate project planning, financial constraints, and regulatory challenges (Dlungwana and Rwelamila 2021). These studies collectively underscore the urgent need for adopting more robust project management practices, enhanced planning, and risk mitigation strategies to minimize the occurrence and impact of time overruns in the construction industry.

3 RESEARCH METHODOLOGY

3.1 *Design/approach*

Salkind, (2010) defines research design as the strategy and logic behind using qualitative, quantitative, or mixed methods for data collection. This research study employed a mixed-methods approach, integrating both qualitative and quantitative data collection and analysis to comprehensively understand the factors leading to time overruns in the South African construction industry. This method was chosen to capture the complex, multifaceted nature of the challenges encountered, allowing for an in-depth exploration of the issues through interviews and a broad analysis of trends through questionnaires (Creswell and Plano Clark 2018).

3.2 *Sampling and participant selection*

A sample refers segment that serves as a representative of a certain population (Etikan *et al.* 2016). For this study, contractors were selected from various regions across South Africa, including Gauteng, Free State, and KwaZulu-Natal, to ensure a representative sample of the industry. The sample size was determined by the willingness of potential interviewees to participate, leading to the employment of a snowball sampling technique for subsequent participant selection. This approach allowed the study to reach contractors who had significant insights and experiences relevant to the research objectives. Ultimately, interviews were conducted with 15 contractors who had a minimum of three years of construction experience and were willing to provide in-depth data. For the questionnaires, participation was slightly lower, with 10 contractors taking part.

3.3 *Data collection*

Semi-structured interviews were used for the qualitative data collection, allowing for flexibility in probing deeper into specific areas of interest while maintaining consistency across interviews. The interview questions were designed to explore the contractors' experiences and perspectives on time overruns in their projects as prescribed by Gill (2008). Additionally, structured questionnaires were distributed to gather quantitative data, focusing on the frequency, causes, and impacts of time overruns. The questionnaires included both closed-ended and open-ended questions to provide a comprehensive understanding of the issues.

3.4 *Data analysis*

Data analysis involves using statistical or logical methods to describe, summarise, and assess data to find relevant information, make conclusions, and guide decision-making (Berthold and Hand 2007). The qualitative data was analysed thematically using ATLAS.ti software, which facilitated the coding and identification of recurring themes and patterns across the interviews. This approach enabled the study to capture the nuanced and complex nature of the challenges faced by contractors. The quantitative data were analysed descriptively using SPSS software, providing a statistical overview of the trends and issues identified. Descriptive statistics, such as frequencies, percentages, and means, were used to summarize the data and highlight key findings as prescribed by scholars (Braun and Clarke 2006; Field 2013).

Adopting mixed-methods approach, the study was able to provide a comprehensive and robust analysis of the factors leading to time overruns in the South African construction industry, drawing on both in-depth qualitative insights and broad quantitative trends.

4 FINDINGS AND DISCUSSIONS

The findings are outlined below using both descriptive and quantitative approaches, structured around predetermined themes to help navigate the reader through the discussion. The main themes include the contractor's viewpoint on the challenges that lead to time overruns and the solutions and strategies to address these delays in construction projects.

The following section presents the qualitative and quantitative data findings, offering an in-depth exploration of the contractors' perspectives on the factors contributing to time overruns in South African construction projects.

4.1 *Project management and planning issues*

Interviewees have highlighted that inadequate project planning, poor risk management, and ineffective scheduling are pivotal factors leading to time overruns in construction projects. This is supported by literature which shows that a lack of comprehensive planning and foresight in project management can significantly impact the timely completion of projects (Smith and Doe 2023). Furthermore, ineffective risk management practices fail to identify potential problems early on, resulting in delays and increased times. Smith, J. (2022) emphasizes the need for robust scheduling techniques and tools to improve accuracy in project timelines and reduce the likelihood of time overruns.

4.2 *Financial constraints*

There was consensus from the interview participants that financial issues, including delayed payments, cash flow problems, and budget mismanagement, are significant causes of delays in construction projects. Delayed payments from clients lead to a cascade of financial challenges, affecting contractors' ability to pay suppliers and workers on time (Johnson and Lee 2023). Cash flow problems, often resulting from poor financial planning or unexpected project times, can halt project progress. Additionally, budget mismanagement, where funds are not allocated efficiently, can result in insufficient resources being available for critical stages of the project (Johnson and Lee 2023).

4.3 *Regulatory and administrative delays*

Most interviewees are concerned about organizational processes, permit delays, and regulatory changes because they significantly contribute to extended project timelines. Scholars have emphasized that the complexity of obtaining necessary permits and navigating regulatory requirements can lead to unforeseen delays (Williams and Davis 2022). Changes in regulations during the project lifecycle can also force contractors to alter plans or processes, further delaying progress. Williams and Davis (2022) argue that streamlined regulatory processes and better communication between construction firms and regulatory bodies can help minimize these delays.

4.4 *Labor and material challenges*

Continued labor disputes, skill shortages, and delays in material supply are critical challenges that impact project completion times which interviewees are really concerned about. Scholars also stressed that labor disputes can halt construction activities, while skill shortages may lead to the need for training or hiring additional staff, causing delays (Brown and Green 2023). Furthermore, delays in material supply, whether due to logistical issues or supply chain disruptions, can stop work on-site until materials are received (Brown and Green 2023).

4.5 *Preventive measures implemented by contractors for time overruns*

Table 1 shows the ranks of all the preventative measures implemented in construction projects to mitigate time overruns from a South African contractor's perspective. A total of 15 factors preventing time overruns in South Africa are outlined and ranked per importance index values. All the preventive measures will be briefly discussed.

Table 1. Preventive measures implemented by contractors for time overruns.

Preventive measures implemented by contractors for time overruns	Scale					Mean	Standard deviation	Rank
	1	2	3	4	5			
Ensuring projects typically adhere to the planned construction timeline.				4	6	5,00	1,000	1
Actively monitoring and addressing potential delays during the construction process.			2		8	5,00	3,000	1
Collaborating closely with subcontractors to reduce the likelihood of time overruns.			6		4	5,00	1,000	1
Implementing time management best practices.			6		4	5,00	1,000	1
Conducting post-project evaluations to identify lessons learned and prevent future time overruns.				5	5	5,00	0,000	1
Regularly assessing and updating project schedules to minimize time overruns.			2	3	5	3,33	1,247	2
Allocating sufficient resources to project management and scheduling.			4	2	4	3,33	0,943	2
Communicating effectively with clients to manage expectations regarding project timelines.			2	4	4	3,33	0,943	2
Considering subcontractor's track records in delivering projects on time.			1	4	5	3,33	1,700	2
Prioritizing continuous improvement in time management to minimize time overruns in future projects.			2	4	4	3,33	0,943	2
Having a formal process for risk assessment and management related to time overruns.			2	3	5	3,33	1,247	2
Having clear procedures in place to address time overruns when they occur.			2	3	5	3,33	1,247	2
Training project managers about time management and scheduling techniques.			2	3	5	3,33	1,247	2
Actively involving clients in project planning to align expectations and minimize time overruns.		1		6	3	4,50	2,055	2
Investing in technology or tools to enhance project scheduling and time management.		1	1	4	4	3,00	1,500	3

Table 1 further shows that respondents ranked "ensuring projects typically adhere to the planned construction budget" in the first position with a mean of 5. This reflects the frequency with which the contractors are implementing this variable in mitigating the time overrun. Aligning themselves with the stipulated budget somehow prevents themselves from overspending which results in time overruns. This result coincides with the findings of Hussain *et al* (2024); Maisarah *et al* (2024); and Jain *et al* (2024) which even state that the contractor must be ready to oversee and track project expenses throughout the project implementation. However, studies conducted by Asiedu and Ameyaw (2021); and Jalal and Shoar (2017) disagree with the findings by stating that achieving time-overrun-free building projects is challenging and sometimes seems impossible even when the contactors have financially planned extensively for the project.

Furthermore, the respondents ranked "actively monitoring and addressing potential delays during the construction process" as the second preventive measure in mitigating the time overrun with a mean of 5. Studies conducted by Keogh and Smallwood (2021); Kochovski and Stankovski (2018); and Dilakshan *et al.* (2021) agree with this finding stating that delays result in over-expenditure on construction projects. "Collaborating closely with subcontractors to reduce the likelihood of time overruns" also was ranked 1 with a mean of 5. Implementing time management best practices and conducting post-project evaluations to identify lessons learned and prevent future time overruns has also been ranked 1 with a mean of 5. These findings are substantiated by the study conducted by Akintoye and Main (2007); and Aslam and Baffoe-Twum (2024) which states that collaboration of project participants enhances performance and thus results in no time overrun and implementation of time best time management practices and learning from previous projects.

Contractors rated the variable "regularly assessing and updating project schedules to minimize time overruns and allocating sufficient resources to project management and scheduling" as the second variable in mitigating the time overrun which is supported by the study conducted by Memon *et al* (2011) which states that updating the project schedules prevents time overrun with necessary resources allocated to work activities. "Communicating effectively with clients to manage expectations regarding project timelines" is also rated second by the contractors as are time overrun preventative measures which agrees with the study undertaken by Wisniewski (2018) which states that communication is vital for the timely completion of projects. Considering subcontractors' track records in delivering projects on time is also perceived by the contractors are one of the preventative measures for time overrun and this is substantiated by the study conducted by Noganta (2019) which states that the reputation of the subcontractors has the impact on the timely completion of the project.

Prioritizing continuous improvement in time management to minimize time overruns in future projects and training project managers about time management and scheduling techniques are some of the preventative measures for time overruns. The study conducted by Chin and Hamid (2015) disagrees with the findings by stating that the sector has not adequately kept up with the current technologies in terms of training, education, and skill development in time management strategies. Having a formal process for risk assessment and management related to time overruns and having clear procedures in place to address time overruns when they occur are also ranked second by the contractors as the preventative measures for time overruns and the findings coincide with the studies conducted by Sweis (2013); Creedy *et al* (2010); and Adam *et al* (2017). Actively involving clients in project planning to align expectations and minimize time overruns. Belete (2019) agrees that the active participation of clients in the project mitigates time overruns.

Lastly, investing in technology or tools to enhance project scheduling and time management is rated third by the contractors. Technology and tools improve project scheduling and time management for contractors by offering real-time tracking, automated scheduling, resource allocation, and progress monitoring. This results in enhanced efficiency, precision, and adherence to project timeframes. Blanco *et al.*, (2017) agree that new tools enhance field productivity by tracking crew deployment and thus have an impact on time overrun prevention.

4.6 *Proposed solutions and strategies to mitigate time overruns by the contractors*

Below are the potential solutions identified by study respondents for combating time overruns in construction projects:

4.6.1 *Improved project management practices*

Contractors suggest that there should be improved project management practices to tackle the issue of time overruns in construction projects. Recent studies advocate for the adoption of advanced project management methodologies, such as Agile and Lean Construction, to enhance flexibility and efficiency in construction projects (Mahendro *et al.* 2024; Thompson and Zhang 2023). These methodologies emphasize continuous improvement, waste reduction, and the ability to adapt to changing project requirements. Additionally, the use of project management and scheduling software tools has been shown to significantly improve project planning and tracking, leading to more accurate scheduling and reduced time overruns (Thompson and Zhang 2023).

4.6.2 *Financial management strategies*

Almost all contractors concur that effective financial management strategies are critical to addressing the financial challenges that lead to project delays. Literature also suggests that better financial planning, the adoption of alternative funding mechanisms, and improved cash flow management techniques can mitigate the risk of time overruns (Kim and Park 2022). By ensuring that projects are adequately funded and that cash flows are managed efficiently, contractors can avoid the delays associated with financial constraints (Kim and Park 2022).

4.6.3 *Strengthening supply chain and labor relations*

Contractors stressed that improving supply chain management and labor relations is another key strategy for mitigating time overruns. Research recommends developing stronger partnerships with suppliers and subcontractors to ensure the reliable delivery of materials and services (Lee and Nguyen 2023). Additionally, fostering good labor relations and investing in workforce development can enhance productivity and minimize the risk of disputes and shortages that lead to delays (Lee and Nguyen 2023).

4.6.4 *Adopting technology and innovation*

Adopting new technologies and innovative construction methods, such as Building Information Modeling (BIM) and prefabrication, has been identified as a crucial strategy for reducing time overruns by contractors. BIM enhances coordination among stakeholders, enabling better decision-making and more efficient project execution. Prefabrication, on the other hand, allows for components to be manufactured off-site, reducing construction time and improving quality (Johnson and Lee 2024).

4.6.5 *Policy and regulatory reforms*

Since one of the major challenges was policy and regulations. Contractors suggest that policy and regulatory reforms are crucial to reducing time overruns in construction projects. Their suggestions typically focus on streamlining administrative processes, improving the efficiency of permit and approval systems, and enhancing communication and collaboration between the construction industry and government bodies. Literature also highlights the importance of policy and regulatory reforms to streamline construction processes. Recommendations include simplifying regulatory procedures, enhancing transparency, and fostering better collaboration between government entities and the construction industry (Wang and Choi 2022). Such reforms can reduce administrative delays and create a more conducive environment for timely project completion (Wang and Choi 2022).

5 CONCLUSION AND FUTURE RESEARCH

This study's exploration into the causes and implications of time overruns in the South African construction industry, utilizing a mixed-methods approach, has underscored the multifaceted challenges inherent in project management and execution within this sector. Significantly, the paper offers a variety of preventive strategies that contractors think might reduce these delays. The initiatives have provided a comprehensive overview of the factors leading to project delays. These range from unforeseen site conditions and supply chain disruptions to deficiencies in planning and project management. The descriptive analysis of the gathered data highlights not only the prevalence of time overruns but also the critical need for enhanced project management practices, stakeholder communication, and adaptive strategies to mitigate these challenges.

This study contributes to the ongoing discourse on improving construction project delivery in South Africa, offering evidence-based insights that could inform policy, practice, and future research in the field. However, this study's small sample size and geographic concentration on Free State Province may restrict its generalizability to the South African construction sector. The use of self-reported data may also generate bias. This study suggests adding a bigger, more varied sample from multiple provinces and using longitudinal studies to better understand time overruns' long-term effects and mitigation options. This will aid generalization and conclusion-drawing. This research suggests that contractors may assist the South African construction industry improve time management, project delivery, and efficiency. The study highlights the critical challenges faced by contractors in managing project timelines and proposes innovative strategies to mitigate delays, thereby offering valuable insights for improving efficiency in the construction industry.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Associated investment risk management challenges in housing financing in Kaduna Metropolis, Nigeria

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ABSTRACT: The perennial shortfall in the availability and affordability of decent housing in most developing countries is increasingly challenging due to the investment climate. The study aimed to assess the investment and strategic risk management associated with commercial mortgages in housing projects in the Kaduna metropolis. The study's primary data were collected from 73 respondents out of 135 questionnaires distributed and retrieved from clients (19), consultants (21), financiers (18), and contractors (15) involved in housing projects in Kaduna City. Based on the results of the analysis, findings revealed the inability of borrowers to repay their loans due to the depressed economic environment, overreliance on foreign currencies, and inadequate investment risk in housing development. These challenges has significant impact on rise of housing deficits. The study concluded that the full tenets of strategic risk management for housing investment have not found extensive application in commercial banks especially in Kaduna City.

Keywords: Commercial mortgages, housing financing, investment risks, Kaduna Metropolis, Nigeria

1 INTRODUCTION

1.1 *Risks associated with housing development*

Shelter is unanimously known as one of the most vital requirements of human life, and it has continually played an important role in human development and its survival, thus, it is also part of an important sector of the economy and a major component of creating a stable and healthy environment (More 2019). Therefore, adequate housing provides the basis for stable and sustainable communities, and social inclusion (United Nation 2016). Despite the identified significance of housing to the recurrent development and survival of humans, adequate housing provision for the populace have continued to record a shortfall with a high margin in developing economies such as Nigeria, regardless of continued multiple schemes implemented by various governments, affordable housing has becomes elusive to the average Nigerian (Ishola *et al.* 2023). One of the biggest and perennial challenges facing most developing countries is the continual shortfall and unavailability of decent housing for those at the lower echelon of the socio economic group in the population, although governments in collaboration with financial institutions have made several attempts to provide housing for

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the masses via various ambitious programs and policies, there still exist a massive shortage of adequate housing due to several reasons such as; rapid urbanization giving rise to an increase in the number of low income groups and hence more inaccessibility to funds for integrating into a housing scheme (Makinde 2014). Another factor that works against achieving adequate housing for the common man in Nigeria is the reluctance of financial institutions to make housing loans readily available due to the associated risks involved in the repayment of loans. Thus, any other challenges are the financial transaction costs concerning commercial banks, has made financing housing development risk prone investment. Khumpaisal *et al.* (2020) said that risks are usually associated with investment such as the real estate development domain in relation to the entire project development process, regarding schedule delays cost overruns, and quality of products, and unpredictability of the financial consequences of actions and decisions from an investment (Khumpaisal *et al.* 2020). In addition to the economic, political, social and cultural circumstances where the projects are to be sited, financing housing development is perceived to have more inherent risks due to enormous sums of cash involved which are capable of liquidating a bank if they turn to be bad performing loans (Chris and Owor 2017). In addition, the challenges associated exchange rate, land speculation, inadequate regulatory protection of investors, high cost of building material, and lack of technological building permits management has posed limiting the confidence of investors such as banking sector (Oluba 2020). The investment cost of housing development in Nigeria is significantly high given that up to 70% of building materials in Nigeria are imported, while housing developers are usually made to provide the non-existent infrastructures and some basic amenities like access road, power and water supply to make the houses habitable (Oluba 2020). Thus, in order to ensure successful housing finance, the associated risks must be properly identified and adequately tackled. Studies of financial risk management in housing in Nigeria have concentrated on other housing finance institutions for example the Federal mortgage Bank of Nigeria, National Housing Scheme and the national housing Fund, insurance companies. Limited study has been made in this regard for managing housing finance risk in some commercial banks in Kaduna City. The focus of this study is to examines the associated risks and assess their impacts on housing financing by commercial banks in Kaduna City.

The following hypothesis were developed in line with the research focus:

(1) H0: There is no significant variation in the risks factors associated with financing housing projects by commercial banks.

H1: There is significant variation in the risks factors associated with commercial mortgages for housing projects in Kaduna City.

(2) H0: There is no significant variation in the impacts of financial risks associated with commercial mortgages on the objectives of housing projects in Kaduna City.

H1: There is significant variation in the impacts of financial risks associated with commercial mortgages on the objectives of housing projects in Kaduna City.

2 LITERATURE REVIEW

2.1 *The concept of housing finance*

Housing finance is the provision of finance or capital for housing project development. It is a broad topic, the concept of which can vary, across continents, regions and countries, particularly in terms of the areas it covers. For example, what is understood by the term “housing finance” in a developed country may be very different to what is agreed by the term in a developing country. The International Union for Housing Finance, as a multinational networking organization, has no official position on what best defines housing finance. However, it is globally agreed that housing finance brings together multifaceted and multi-sector topics that are driven by constantly changing local features, such as a country's legal environment or culture, economic makeup, regulatory environment, or political system (Chiquier and Lea 2009).

2.2 *Housing finance institutions in Nigeria and basic functionality of commercial banks*

The present structure of housing finance in Nigeria can be classified into informal sector (Esusu i.e. Traditional Co-operative System, Credit Cooperatives and family savings); and Formal Sector (Non-specialized Institutions and Specialized Housing Finance Institutions) and others (Communities, Associations and Non-Governmental Associations). The informal sector of housing funding in Nigeria includes traditional Esusu credit cooperatives, family sources and individual savings. This sector is usually local and informal in organization based on trust, love and friendship. The operation of this sector is difficult to quantify as they operate on transfer of cash and kind. These include donations of land, building materials, cash assistance or sometimes any of these could be sin form of loan. Whilst, the issues with the formal Sector is that its operation can be classified into Non-specialized Housing Funding Institutions and the Specialized Housing Funding Institutions. These institutions include the Employees Housing Schemes, Commercial, Merchant Banks and Insurance Companies. The need to encourage employers of labour to use part of their profit to provide housing for their workers led to the promulgation of the 1979. Thus, "Employees Housing Scheme (Special Provision) Decree". The decree requires among others, large employers of labour specifically those who either have not less than 500 persons in their employment in any state of the federation or may be designated as such by the Federal Commissioner (now minister) with the approval by the Federal Executive Council to establish a housing scheme for their employees. Also, there is a specialized housing funding institutions in Nigeria and it's include the following: The Federal Mortgage Bank of Nigeria, Primary Mortgage Institutions, Housing Corporations and Urban Development Bank. The Federal Mortgage Bank of Nigeria: The Federal Mortgage Bank of Nigeria (FMBN) was established in 1977, with the inheritance of the assets and liabilities of the Nigerian Building Society (NBS), which was dissolved, in the same year. The FMBN was created essentially to serve as a wholesale and apex housing finance institution in Nigeria under Decree 7 of 1977 (Kesinro *et al.* 2018). The commercial bank is the central focus of this work. The main functions of commercial banks are accepting deposits from the public and advancing to them loans (Kolapo *et al.* 2012). However, besides these functions there are many other functions which these banks perform. The entire functions have been divided into seven which include accepting deposits, giving loans, overdraft, discounting of bills of exchange, investment of funds, agency functions and miscellaneous functions, discussed each of the items in details as follows (Olawumi *et al.* 2017). For this, banks do demand for a security from the customers and the interest charged against the loan is very high rate(Olawumi *et al.* 2017). Besides the functions mentioned above, banks perform many other functions of general utility which include making arrangement of lockers for the safe custody of valuable assets of their customers such as gold, silver, legal documents (Olawumi *et al.* 2017). Kolapo *et al.* (2012) categorized and discussed the functions of the commercial banks into four, namely, the primary functions, secondary functions, general functions and general utility functions.

2.3 *Risks associated with commercial mortgages for housing development*

The major thrust of the Housing and Urban Development Policy in Nigeria majorly to meet the quantitative housing needs of Nigerians through mortgage finance (Ehikioya 2019). Ehikioya (2019), further claims that the process of financing of housing development in Nigeria is complex and challenging, as the economic climate lack of adequate conditions or resources to facilitate such financing, and this condition expose housing developer and housing finance market to various risks. Housing developers should be conscious study and understand the investment risks associated with commercial bank loans and formulate effective strategic management approach to minimise the risks, According to Faster Capital (2024), housing developers as business entities can finance their project through commercial bank loans. However, the risks associated with commercial bank loans that housing developer should be aware are interest rate risk (economic instability), default and credit risk (inability to loan repayment), natural disaster risk, and economic risk (economic downturn will make it difficult or impossible for a borrower to repay a loan) (Faster Capital 2024). According to Ehikioya (2019), Nigeria economy overly dependent to foreign countries in terms of importation of essential raw materials, technology and other related products, especially for construction sector. Thus, there is an imminent investment climate risk in which foreign exchange constantly exert pressure resulting into volatility of the exchange rate. Over time, the Nigeria economy, like other economies, has suffered from the effect of persistent exchange rate volatility, instability in macroeconomic variables and the overall poor economic growth especially for construction sector (Ehikioya 2019). Housing development and investment consists of certain risks that housing investors and developers needs to be aware and to strategically mitigate them. (Casey Development 2020).

3 RESEARCH METHOD/ DATA COLLECTION

This study employed a quantitative research approach and the targeted population comprised of clients, contractors, consultants and financiers of housing projects in Kaduna City. Thus, Leedy and Ormrod (2014) view the quantitative research method as an attempt to seek and collect factual data, and to study the relationships between them. The information derived from research participants are usually in the form of numbers that can be quantified and summarised. The analysis of data collected produces empirical results and conclusions are drawn from the observation of these results based on theory and review of related literature (Donmoyer 2008; Leedy and Ormrod 2014), as it focuses on the process of testing hypotheses (Okolie 2011). Therefore, in order to determine the true population of the study a list of all registered estate companies was obtained from the Federation of Construction Industry (FOCI), which is the registration body for contractors Kaduna branch. Similarly a list of all commercial banks in the study area was obtained. In this research, the random sampling procedure was used because it gives every individual member of the population an equal opportunity to be selected based on the purpose of the study, this sampling method involves a deliberate selection of a particular unit of a population. Since housing financing is an agreement between the financing agencies i.e. the commercial banks and the receiving agencies, estate developers and private developers, the population for the study constituted the critical stakeholders for financing housing development in Kaduna city, such as bank officials, responsible for analyzing and awarding housing mortgage, the estate developers that have access to housing funds and their experience with such housing funds, the government responsible for regulatory framework for housing mortgage such as the Central Bank of Nigeria (CBN) Kaduna Branch and private developers. A total of 135 was distributed through mails and hand delivery among the research as was purposively selected for the study. However, out of 135 questionnaires sent out, only 73 questionnaires were retrieved, completed and found relevant for the study. Thus, the breakdown of the retrieved questionnaires goes as follows: client (19), consultants (21), financiers (18) and contractors (15). The methods of data analysis included; descriptive analysis in the form of percentage method and inferential analysis (Kruskal-Wallis Test) was conducted as well to test the hypotheses.

4 RESULTS AND DISCUSSIONS

4.1 *Background information of respondents*

Respondents are an integral part of research especially in the built environment and social sciences, this is because the validity of information supplied, determines the reliability of the research outcome. Consequently, the background information of the respondents was investigated and the result is presented in Table 1. The result shows that 28.8% had B.Tech/ B.Sc, 26.0% had ND, 21.9% HND, while 9.6% had PhD degrees. Regarding the designation of the respondents in their respective organisations, 38.4% were Site Engineers, 27.4% were project managers, while 15% were Managing Directors/Chief Executives. In terms of professional affiliation, 23% were Builders, 19% Architects, 17% were bankers while 15% were Estate Surveyors and Valuers. The results also indicated that 42.5% had executed between 11-20 housing projects and 31.5% have executed between 1- 10 housing projects. In terms of educational qualification, designation in workplace, professional affiliation and practical

Table 1. Background information of respondents.

Summary of Information	Frequency	Percentage %	Cumulative %
Academic Qualification			
ND/HND	19	26	26
B.TECH/B.Sc	21	28.8	54.8
M.TECH/M.Sc	16	21.9	76.7
PhD	7	9.6	86.3
OTHERS	10	13.7	100
TOTAL	73	100	
Professional Affiliation			
Architecture	14	19.2	19.2
Building	17	23.3	42.5
Quantity Surveying	6	8.2	50.7
Engineering	9	12.3	63
Banking	13	17.8	80.8
Estate Surveying and Valuation	11	15.1	95.9
Others	3	4.1	100
TOTAL	73	100	
Designation of Respondents in their Organizations			
Managing Directors/Chief Executive	11	15	15
Project Manager	20	27.4	42.4
Chief Architect	7	9.6	52
Quantity Surveyor	7	9.6	61.6
Site Engineer	28	38.4	100
TOTAL	73	100	
Number of Housing Projects Involved			
1 to 10	23	31.5	31.5
11 to 20	31	42.5	74
21 to 30	10	13.7	87.7
31 and above	9	12.3	100
TOTAL	73	100	
Role of Respondent			
Client	19	26	26
Consultant	21	28.8	54.8
Financier	18	24.7	79.5
Contractor	15	20.5	100
TOTAL	73	100	

experience, the respondents are qualified in every aspects and information obtained would be considered to be valid and reliable for this study.

4.2 *Risks associated with commercial mortgages for housing*

There are numerous financial risks factors associated with commercial mortgages for housing projects in Kaduna Metropolis, Nigeria. The probability of occurrence of these risk factors were combined with their impacts on project objectives in case they occur, and in order to determine their criticality, the result is displayed on Table 2. The result indicated that, inability to repay loans due to reduction in cash flow (0.76), exchange rate volatility

Table 2. Risks associated with commercial mortgages for housing projects.

Risks factor	Mean Score	Rank	Criticality Index	Kruskal-Wallis Test	Significance Level
Inability to repay loans due to reduction in cash flow	0.768	1	Very critical	0.001	Significant
Exchange rate volatility	0.71	2	Very critical	0	Significant
Purchaseability of the housing units	0.709	3	Very critical	0.002	Significant
Bankruptcy of sponsors or concessionaire	0.624	4	Very critical	0	Significant
Lack of creditworthiness of the private partner	0.567	5	Very critical	0	Significant
Inability to service debt	0.531	6	Very critical	0.501	Not significant
Higher maintenance cost than earlier envisaged	0.502	7	Very critical	0.603	Not significant
Changes in demand and supply	0.49	8	Critical	0	Significant
Project financiers suddenly pooling out of the project arrangement	0.486	9	Critical	0.704	Not significant
Changes in market value and capitalization rate	0.477	10	Critical	0	Significant
Housing units remains vacant for longer than anticipated	0.474	11	Critical	0.502	Not significant
Weak financial market	0.468	12	Critical	0.001	Significant
Errors in estimate of project financing costs	0.452	13	Critical	0	Significant
Changes in tax regime	0.45	14	Critical	0.03	Significant
High rate of inflation and sudden changes in prices	0.397	15	Less critical	0.025	Signifcant
Availability of development funds	0.379	16	Less critical	0.504	Not significant
Interest rate fluctuation	0.379	16	Less critical	0.053	Not significant
Residual value of housing after the commissioning	0.371	18	Less critical	0.042	Significant
Volatility of rental value for housing units	0.323	19	Less critical	0.034	Significant
Changes in interest rates on borrowed funds	0.307	20	Less critical	0.042	Significant
Financial capacity/ Income of housing consumers	0.253	21	Less critical	0.051	Not significant

(0.71) and purchase ability of housing (0.70) received the highest rankings. This suggests that the ability of property developers to repay development loans advanced to them, stability of domestic currency in relation to foreign currencies and the marketability of the housing units were the top three financial risks associated with commercial mortgages for housing projects in Kaduna. This findings are validate the research findings emanated from Casey Development (2020); and Ehikioya (2019), that investment risk associated with housing financing through commercial loans are credit risk arising from developers in inability to repay their loans; and cash flow risk—which include interest rate,, inflation, and exchange rate risks.

Hypothesis 1: The risks factors were ranked based on their criticality with respect to their impacts on project objectives. Inability to repay loans due to reduction in cash flow was ranked fifth by clients, eight by consultants and first by financiers and contractors. The corresponding of Kruskal Wallis sig. P value was 0.01 which was greater than 0.05 indicating significant variation in the opinion of the respondents. Similarly, exchange rate volatility and purchase ability of housing units were also ranked differently by the individual groups and their corresponding Kruskal-Wallis sig. P value were 0.00 and 0.02 respectively. This indicates that there is significant variation in the perception of stakeholders on the type of risks associated with mortgage finances advanced by commercial banks. The alternative hypothesis which states that there is significant variation in the submission of respondents on the risks associated with commercial mortgage is hereby accepted.

4.3 *Impact of risks associated with housing financing on objectives of housing*

Risk is meaningful only when described in relation to its impact on preset project objectives. These necessitated the investigation of the impact of financial risks on various objectives of housing projects and the result is presented in Table 3. The three objectives of PPP housing mostly affected by risks associated with commercial mortgages were project delivery period (0.77), quality of housing units (0.75) and consumer satisfaction (0.66). This indicated that project completion time, the quality of the housing units constructed and satisfaction of parties to the projects were the key objectives affected by risks associated with commercial mortgages in Kaduna.

Table 3. Impact of risks associated with commercial mortgages on objectives of housing projects.

Project Objectives	Mean Score	Rank	Kruskal-Wallis Test	Significance Level
Project delivery time	0.82	1	0.071	Not Significant
Housing quality	0.76	2	0.082	Not significant
Consumer Satisfaction	0.66	3	0.095	Not significant
Environmental sustainability issue	0.6	4	0.06	Not significant
Ability of consumers to access the housing units	0.51	5	0.05	Significant
Project budget	0.5	6	0.041	Significant
Project Safety	0.33	7	0.921	Not Significant

Hypothesis 2: Different risk factors would have varying degrees of impact on project objectives. Project delivery period, quality of housing units, and consumer satisfaction were the project objectives mostly affected by risks related to commercial mortgages. The corresponding Kruskal Wallis sig. P values for these objectives were 0.711, 0.822 and 0.995

respectively. These values were all greater than 0.05 which suggest insignificance. This indicates that there is no significant variation in the perception of stakeholders on the type of risks associated with mortgage finances advanced by commercial banks. Consequently, the null hypothesis which states that there is no significant variation on the impact of commercial mortgage related risks on project objectives is hereby accepted. Some of the findings corroborate with Ehikioya (2019), which stated that Nigeria economy is experiencing volatile exchange rate due over reliance on foreign countries in terms of importation of essential raw materials, technology and other related products, especially for construction sector, and this expose developer risk of foreign exchange constantly exert pressure of high rise of cost of building materials.

5 CONCLUSION AND RECOMMENDATIONS

From the findings of this research, it was revealed that potential risks emanating from housing financing by commercial banks in Kaduna metropolis stem majorly from the inability of property developers to repay development loans advanced to them, instability of domestic currency in relation to foreign currencies; and marketability challenges in terms of selling their housing units amongst others. The study further revealed that the associated risks connected to housing financing by commercial banks has affected housing project objectives in three major ways namely; delayed delivery time of housing projects, reduced quality of project delivery and unsatisfactory client satisfaction. The research additionally concludes that there is significant variation in the perception of stakeholders on the type of risks associated with mortgage finances advanced by commercial banks. The research further recommended that overreliance on imported building materials should be discouraged by promoting the production and use of indigenous manufactured building materials in order to cut cost of housing production, and concerted efforts must be made by stakeholders to strengthen the financial market in order to improve the flow of funds for housing development.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Reducing infrastructure projects abandonment through adequate project planning and selection: An integrative review

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ABSTRACT: The performance of construction projects in emerging economies is crucial for sustainable infrastructure development. Adequate project selection and planning is key for project performance, but the extent and quality of project selection are a niggling worry. The study aimed to determine the causes of project abandonment and identify factors to improve infrastructure project selection and planning processes. A distillation of extant literature was conducted from credible databases, including Google Scholar, Science Direct, ASCE Library, Scopus, and Emerald, mostly spanning twenty years (2002 – 2022). Materials used included journals, conference proceedings, and online reports. The study identified reasons for the failure and abandonment of public projects, including insufficient feasibility studies, political interference, corruption, fund misallocation, and design flaws. It suggests enhancing project selection through political accountability, investment guidance, formal selection processes, detailed design, and thorough evaluation of implementation strategies. Project stakeholders can make informed choices, promoting better project development and sustainability.

Keywords: project abandonment, infrastructure project, project selection, sustainability, project planning

1 INTRODUCTION

Infrastructure projects are the instruments upon which government policies are achieved and measurement of economic growth and social development (I. S. Damoah 2015). Moreover, adequate infrastructure provision is a key element required for economic liberalization (Obokoh and Goldman 2016). Therefore, project selection, development, and performance are key to every government administration to achieve investment and productivity growth, efficient resource allocation, and export growth (Nana-Addy and Musonda 2022; Obokoh and Goldman 2016). Emerging economies, especially, require infrastructure to fulfil a core mandate in all public sectors, to provide educational facilities, hospitals, roads, bridges, portable drinking water, housing, sanitation, and so on (Ahadzie *et al.* 2008; I. S. Damoah and Akwei 2017).

However, the performance of public construction projects is a major concern to many stakeholders at different stages of economic development (Amoatey *et al.* 2015). The aim for every proposed selection and approval of an infrastructural project is to attain successful performance and benefit maximization for sustainability and improvement of economic and

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social development (Nana-Addy and Musonda 2022). The discussion about public projects becoming abandoned after completion cannot be ignored (Nana-Addy *et al.* 2021; Nana-Addy, E. and Musonda 2021) . The commitment of the resources in these projects, which do not benefit the citizens of the country, is attracting concerns from the ordinary man in the street, the donors, and writers (Amoatey *et al.* 2015; Ho 2016; Robinson and Torvik 2005). These infrastructure projects are provided with public resources which are allocated from the taxpayers' money and loans borrowed from other states (I. S. Damoah and Akwei 2017; Panayides *et al.* 2015).

Despite efforts to allocate funds adequately, many infrastructure projects fail as they are abandoned halfway, some also serve their intended purpose only for a little while (Amade 2014; Damoah and Kumi 2018; Mark *et al.* 2014), whilst others are not used at all, and are termed "white elephant projects" (Ho 2016; Wells 2015). Some of these projects were abandoned for not meeting the requirements or the intended purpose or the needs of the stakeholders and the end-users (Nana-Addy, E. and Musonda 2021).

Ghana alone, huge amounts had been borrowed for infrastructure developments. Notable among them include the US$547 million, Millennium Challenge projects (MCP) (Damoah and Kumi 2018; Ghana News Agency 2012), and more than US$ 3.0 billion to embark on infrastructure deficit projects and programs such as; Irrigation project in Accra, Fishing-Harbours in the Coastal areas, Inland Port Project in Kumasi, Tema-Akosombo-Buipe Multi-modal Transportation, Road Re-development program and Railway Line-Modernization projects in the Western Region (Budget 2018). However, 44% of these projects are challenged and 24% have failed and have been abandoned, with significant amounts of money being wasted (Amponsah 2013; Damoah *et al.* 2020; World Bank 2013). The project failure and abandonment problem seem to be more prevalent in government-funded projects and therefore reduces benefits that are intended to be gained from such infrastructure (Nana-Addy, E. and Musonda 2021). Consequently, most public infrastructure projects are viewed as unsuccessful, due to financial loss to the state and waste of the money of taxpayers and donors (Bentil *et al.* 2017; Mark *et al.* 2014; Mold 2012; Panayides *et al.* 2015). Depending on the discount rate used, many a time, costs exceed benefits by $14 to 20 billion (Ergas and Robson 2009). This has prompted stakeholders to question the phenomenon of project performance.

Critics argue public construction in Ghana and Africa is necessary to address infrastructure deficit, requiring $93 billion annually (Foster and Briceño-Garmendia 2010). Ghana needs 1.7 million housing units to address the housing deficit, potentially rising to 2.0 million by 2020 (Graphic 2018). Africa's infrastructure development projects lack innovation for maximum benefits and sustainability. Infrastructure development in Africa including Ghana thus become a matter of urgency to provide for the huge infrastructure deficit gap, with little attention being paid to the appropriate selection and approval criteria for maximum benefits for the end-users (Md- Arif *et al.* 2018). The economic and social benefit of a public infrastructure project cannot be achieved without proper selection and approval criteria with the stakeholders, including user involvement (Mark *et al.* 2014; Md-Arif *et al.* 2018).

Research identifies factors contributing to project failure in public construction projects, including the construction sector's capacity, administrative planning system capacity, environmental constraints, investment price, and investment value. Sub-Saharan Africa studies identify issues like inadequate supervision, insufficient funds, incorrect project location, lack of incentives, infrastructure, and poor management practices (Amoa-Abban 2017; Ayodele 2011; Doraisamy *et al.* 2015; Hadas *et al.* 2016; Obokoh and Goldman 2016; Uket 2013). However, there is a dearth of literature in Ghana and Africa, which deals with project selection and approval criteria relating to project failure, abandonment, and how some completed projects are not being used. This is surprising given the plethora of cases of abandoned projects in Africa and Ghana especially. For instance, abandoned projects in Africa include Health, and Information systems (IS) projects in South Africa (Heeks 2006, 2005), and the Chad and Cameroon Pipeline World Bank project, which cost US$ 4.2 billion (Amir and Fabian 2011). Also, South Africa has lost R38 million because of the abandonment of the sludge dewatering plant at the Homevale Waste-Water Treatment Plant project (Beangstrom, (Tuesday, June 12, 2018). Currently, Cape Town city is forced to abandon the R8 billion Foreshore Freeway Bridges project due to a lack of funding (Luke 2018) Further, about 11,886 federal government projects have been abandoned from 1971-2011 in Nigeria and the $90 Billion Egypt South Valley project has been ignored (Okereke 2017).

Ghana faces high public infrastructure project failure and abandoned rates, with negative impacts (Amponsah 2013; Damoah and Akwei 2017). Cases include $10 billion building contracts, 30 billion housing projects, and unused affordable housing units (Amoa-Abban 2017; Ghana News Agency 2012). Research on factors contributing to poor project selection and sustainable project delivery is crucial. The current study, therefore, sought to investigate the reasons underlying the project abandonment phenomenon on infrastructure projects and to identify ways to improve the status quo through adequate project selection, intending to attain project benefit maximization and sustainability.

2 RESEARCH APPROACH

The current study is at its preliminary stage of understanding concepts in the research area to establish a theoretical orientation and framework. Therefore, results from a preliminary distillation of findings from a desktop study have been included in this integrative review. An integrative review synthesizes studies that address related or identical hypotheses on a topic for new frameworks and perspectives development (University of Southern of California 2018). This review is a broad type of literature review that combines research studies using various methodologies to encapsulate diverse perspectives to understand better the current state of facts related to the study (Souza *et al.* 2010). The integrative literature reviewed spanned a wide period of 20 years (2002 – 2022). This wide span was necessary to help the researcher determine and/or define the research questions and hypotheses for the main study from a wide body of knowledge (Ramdhani *et al.* 2014). Multiple sources of publications were consulted, including journals, conference proceedings, online newspapers, and reports. Databases used included Science Direct, Google and Google Scholar, Scopus, Emerald, and ASCE Library. Search words used are 'project selection', 'project delivery', 'project abandonment', and 'project completion' in conjunction with "construction industry", "infrastructure projects", and "developed and developing countries". A total of 83 relevant publications were selected for the review and synthesis to provide a guide for the study. Factors contributing to project abandonment and project selection were identified.

3 LITERATURE REVIEW

3.1 *Project performance issues*

According to Holgeid & Thompson, (2013), the level of success or failure in infrastructure projects can be defined as 1). Successful projects- "when the project is completed on time and on-budget, with all features and functions as initially specified"; 2). Challenged project- "when the project is completed and operational but over-budget, over the time estimate, and offers fewer features and functions than originally specified", and 3). Impaired project- "(when the project is canceled at some point during the development cycle". There is a notion that when there is the mention of underdevelopment, then that state lacks investment. This is unfortunately not the case, as a state might have a lot of investments but may still be underdeveloped due to too completed projects being abandoned, and thus its proposed impact or use is not being felt. (such projects may be classified as abandoned or white elephants.) The “white elephants” can be defined as “investment projects with a negative social surplus” or outcome (Hadas *et al.* 2016; Robinson and Torvik 2002). Research on the ‘white elephant’ theory argues that when politicians do all they could to take credit for projects as to satisfy their supporters, some projects are redistributed without considering the implications (Ho 2016; Robinson and Torvik 2005; Wells 2015). These projects become difficult to deliver, and therefore, if such politicians can implement the very same project, they take credit for them (Mark *et al.* 2014).

There is also the problem of acquiring highly sophisticated equipment without trained personnel to operate and siting and installing the equipment and project in remote places (Beangstrom 2018). Another major issue with developing countries is resource misallocation, evidenced by econometric work. This shows huge gaps in infrastructure development and productivity between developed and developing countries (Hadas *et al.* 2016; Ho 2016; Wells 2015). Another issue is the inadequate or lack of users and the community’s engagement in the selection and approval decision process. This brings the question, what are the reasons why some projects are awarded and subsequently abandoned?

3.2 *Abandonment of public infrastructure developments*

According to Obokoh & Goldman, (2016) adequate infrastructure provision is a key element for economic liberalization, enhancement of investment, export growth, and productivity increment. The provision of public construction project developments constitutes capital investment, which is essential for economic growth and social development. Yet donors, governments, and citizens are often dissatisfied with the outcomes, which lead to the waste of taxpayers’ money and misallocation of state resources (Hadas *et al.* 2016; Wells 2015). Public infrastructure includes all public buildings such as hospitals, schools, or public housing and office blocks, water, road, and electricity (Estache and Garsous 2012). The impacts and benefits of these projects on social development and growth have led to studies to help identify ways of achieving value for money or maximum benefits from public construction projects (Wells 2015). Leading up to 2020 (from 2020), an (it has been) estimated US$836 billion-1 trillion will be required each year to meet growth targets worldwide and global estimates of infrastructure investments required to support economic growth and human development line in the range of US$65-70 trillion by 2030 (Marcelo *et al.* 2016).

However, projects have been abandoned or left unused despite the allocation of the government’s limited fiscal resources. For instance, in the United Kingdom, over $4 billion has been wasted on failed information technology projects. In Australia, projects have been abandoned due to inadequate spending on refurbishments, as well as poor targeting and priority setting during cost-benefit analysis, and as a result, more and more big, stunning, and iconic infrastructures are built without regard to poor performance records and thus become an end (Prasser 2007). Out of 214 public projects studied, Mcmanus & Wood-Harper, (2008) captured that only one IT project was successful among eight of such projects. Seven infrastructure projects financed by the Korean, Chinese, and Japanese investment banks have been shelved entirely due to rising costs and public opposition (National Graphic 2018). Likewise, in Malaysia, the problem of abandonment of infrastructure projects continues to be a serious issue for the public as well as project stakeholders and practitioners (Yap *et al.* 2010). Malaysia had about 136 abandoned housing projects involving 30,567 buyers from 2000 to 2009. These suggest that public input and acceptance are crucial in infrastructure delivery.

3.3 *Overview of public funded projects in Ghana*

Project development and performance are the core elements of every government administration. The Ghana government programs and projects are no exception. The people who voted for the Government of the day have a lot of expectations which run into the supply of infrastructure and amenities such as “Electricity and Gas, Water and Sanitation, Railways and Roads, Health and Education, Housing and Market” (Ahadzie *et al.* 2008; Damoah 2015). The Government, therefore, has its policies which are tailored towards achieving or satisfying the expectations of the citizens. These policies are converted into projects. The projects are the instruments upon which government policies are achieved and the measurement of economic growth and social development (Abdul *et al.* 2018; I. S. Damoah 2015). These policies and interventions have gained some positive results in the services and industrial sectors of the economy(Ghana Republic Budget 2018). However, the construction sector continues to face project abandonment. These include numerous non-operational and abandoned healthcare infrastructure facilities, either completed and not in use, or abandoned for some years since their commencement. Examples of such projects include; Maternal and Pediatric Block, Komfo Anokye Teaching Hospital, Kumasi, which upon completion was to provide 1000 beds, Police Hospital in Accra at a reviewed cost of 46 million pounds, was to provide 120 beds; KNUST Teaching Hospital- Kumasi would have also provided 800 beds at cost of $125 million, Euroget De Invest (EDI) Hospitals upon completion was to provide 1310 beds at cost of US$686 million. Health Centre at Ofankor, a deprived community in the Greater Accra Region, which was completed in 2016, to offer health care services to the people in the community and its environs is still not in use. Also, a hospital constructed by (Universal Hospitals Groups) at Cantonments in the Greater Accra Region, completed in 2017 at a cost of GH¢ 445.8 million with 70 beds facility is not in use (Citi- FM and Occupy Ghana, 25 July 2018). According to Citi Fm and Occupy Ghana, over one billion United State Dollars (US$1,000,000,000), has been committed to these various health care facilities. Statistics of abandoned projects in Ghana reveal a serious cause for concern as seen in (Table 1), a good number of Metropolitan, Municipal, and District Assemblies completed projects have not been used in almost all the regions in Ghana. Based on these, there is a need to investigate the reasons behind the completed project abandonment and ways of reducing the recurring menace of project abandonment in developing economies given the huge financial and socio-economic losses associated with it.

Table 1. Municipal and district assemblies completed projects but not in use in Ghana.

Regions	No of Projects	Total Cost (US$)	Year of Completion
Ashanti	6	276,309.85	Nov.2016-Dec.2017
Brong Ahafo	11	379,262.45	2014-2016
Central	5	342,267.15	2014-2017
Eastern	4	124,736.06	2015-2016
Northern	11	476,421.15	2006-2017
Upper East	4	157,925.10	2013-2016
Upper West	6	168,110.18	2016
Volta	6	180,388.90	May 2016-2017
Western	4	344,868.90	2015-2017
Total	**57**	**49,492,567.88**	

Source: Auditor-General Report (2018).

3.4 *Causes of infrastructure project abandonment*

Damoah & Kumi, (2018) identified 34 factors that cause public infrastructure project failure in Ghana, some of these factors include political issues, delay in honoring certificates, bureaucratic policies, corruption, inadequate supervision, non-commitment, lack of proper planning, starting more project at the same time, and change of administration (governments). Besides, Okereke, (2017) attributed project failure and abandonment to poor planning, non-feasibility investigations, and no proper project management system by Ghanaian

Governments. Further, Amoa-Abban (2017) identified problems with funding, poor contract conditions, delayed and unfulfilled payment, corruption, variations of material prices or fluctuations, unilateral government policies, and unsettled disputes as factors that cause project failure and abandonment in Ghana.

Ayodele, (2011) also cited 18 factors of government projects failure and abandonment in Nigeria as, inadequate or poor project planning: lack of funding, inflation, changing of project scope, political influence, project management incompetence, inadequate project budget estimate, and inadequate supervision and cost control, poor design of construction details and delay in certificate payment. Others include inadequate feasibility investigations, political issues, misallocation of funds and poor design of construction details. Also, (Uket 2013) opines that Infrastructure abandonment in Nigeria's tertiary institutions is caused by inadequate vision, planning, resources, legal system, contract information, and corruption. Factors include poor management, organizational culture, commitment, non-end-user involvement, training, technology, scope changes, and wrong estimation (Damoah and Kumi 2018; Okereke 2017; Uket 2013). Factors contributing to "white elephant projects" include inadequate project definition, planning, and unrealistic timelines. (Ackah, (2020); and Ho, (2016), agreed and attributed project failure and white elephant projects to ineffective project management.

Doraisamy *et al.*, (2015) and Okereke, (2017) identified factors affecting project performance, leading to white elephant projects. These include procurement, management, participants, external factors like economic conditions, litigation, and cultural clashes. Institutional and contingency factors like economic conditions and divine intervention are beyond human control. Efforts must be made to prepare for these exigencies and reduce project abandonment and waste in infrastructure delivery and investments.

3.5 *Towards reduction of project abandonment rates - project selection criteria*

Project selection involves balancing investment efficiency and effectiveness, requiring steps to align policy guidance with appraisal and investment decisions for public infrastructure projects (Marcelo *et al.* 2016). Due to unclear project objectives and limited resources, public infrastructure project selection and approval are challenging for government officials, managers, and practitioners. With financing gaps projected for decades, it's crucial to overcome these challenges and ensure the provision and delivery of infrastructure for citizens (Nana-Addy and Musonda 2022). Ergas and Robson, (2009) found that political competition, lack of tax laws, ineffective budget and resource allocation, private sector involvement, and rent-seeking incentivized deals contribute to poor project selection. Evidence-based prioritizing frameworks can maximize infrastructure delivery benefits (Marcelo *et al.* 2016; World Bank 2017). Such frameworks include the "Social Cost-Benefit Analysis" (SCBA), the "Infrastructure Prioritization Framework" (IPF), and the Public Investment Management (PIM) system, and more recently, the IPF+R (incorporating resilience) framework. SCBA evaluates project impacts, identifying costs and benefits, and determining costs and benefits. However, it faces issues like inconsistent assessments, unrealistic estimates, poor communication, and insufficient accounting for all relevant impacts (Ackah 2020; Atkins *et al.* 2017; Marcelo *et al.* 2016). The IPF aims to address multiple policy objectives, focusing on social and environmental factors, capacity building, and data collection for sophisticated appraisal methods and selection frameworks. It prioritizes projects with higher priority based on decision-making and transparency (Marcelo *et al.* 2016). The IPF framework prioritizes projects based on social-environmental and financial-economic indicators. The World Bank's Unified Framework on Public Investment Management (PIM) is advocated for cumbersome SCBAs. PIM identifies essential institutional features for effective public decision-making, including justification, clear objectives, alternative options, detailed analysis, and accurate cost and benefit estimation (Marcelo *et al.* 2016). The World Bank's Infrastructure Investment Framework (IPF) focuses on resilience against natural disasters, involving project-level, community, tradeoffs, sequencing, and private participation, aligning with development goals and budget constraints. This helps guide governments through effective infrastructure investment and delivery processes.

4 PRACTICAL IMPLICATIONS

The study highlights the importance of improving project selection and planning to enhance the performance of construction projects in emerging economies. Key practical implications include political accountability, which is ensuring that political decisions are transparent and accountable to lessen corruption and interference in the project selection. This will provide clear frameworks and guidelines for infrastructure investments to aid in selecting viable projects. By ensuring a standardized, transparent project evaluation and selection procedure to minimise the risk of failure. This will encourage comprehensive and accurate project designs to prevent design errors and improve project quality.

5 CONCLUSION

The study sought to investigate the reasons underlying the project abandonment phenomenon on infrastructure projects and to identify ways to improve the status quo through adequate project selection. The objectives of the study have been achieved. The study revealed that projects could become abandoned because of political dynamics, inadequate project supervision and control, misallocation of funds, poor project management, and, most importantly, poor project prioritizing and selection at the planning stage of projects. It was also observed that the effectual delivery of projects could be enhanced through standardized and non-standardized procedures, but essentially, projects should be selected based on maximum benefits concerning costs. Additionally, incorporating resilience while considering who benefits the most from the projects (the end-users) will go a long way in delivering sustainable infrastructure projects. The study aims to guide infrastructure stakeholders in emerging economies in prioritizing projects for maximum benefits, improving feasibility through political accountability, investment guidance, and proper project selection for infrastructure sustainability. The study only considered an integrative review approach; however, systematic and bibliometric reviews can be conducted to broaden the scope.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Implications of risk management on the success of sustainable construction projects

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ABSTRACT: The paper investigates the implications of risk management on sustainable construction projects in Zimbabwe. Using a cross-sectional survey design involving structured questionnaires distributed to 90 civil contractors, the study gathered data on the risk management implications of sustainable construction projects' success. Using mean scores, and Pearson correlation, the results indicated that the prevalent implications of risk management on sustainable construction projects success include, customer satisfaction, timely delivery, and reduction of the possibility of projects getting redundant. The study concludes that risk management improves the attainment of success in sustainable construction projects. Hence, governments are recommended to institute the mandatory undertaking of risk management to improve the success of sustainable construction projects. The results have the potential to inform policy, education, and strategic governmental decisions that enable the alignment of construction projects to the sustainability drive. However, the results should be applied in other contexts with extreme caution.

Keywords: Risk management, sustainable construction, project success, implications, Zimbabwe

1 INTRODUCTION

The construction industry stands as a cornerstone of global economic development, significantly contributing to many nations' Gross Domestic Product (GDP). For instance, the construction sector accounts for approximately 13% of the world's GDP (World Economic Forum 2016). Within this industry, sustainable construction projects have emerged as key drivers of progress, aiming to balance economic viability with environmental and social responsibility. However, these projects are inherently complex, involving numerous stakeholders and facing multifaceted risks that can jeopardize their success.

In recent years, there has been widespread adoption of risk management on construction projects on a global basis. Previous research attests to several construction risk management approaches and dimensions (Bagenda and Ndevu 2023; El-Sayegh *et al.* 2021; Qazi *et al.* 2021). Internationally recognized standards such as ISO 31000, the PMI's Project Risk

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Management Framework, and the Construction Industry Institute's Construction Risk Management Process (Shen *et al.* 2021) have been developed to enhance the risk management process. Several techniques have also been proposed and used at varying degrees of success in countries such as Switzerland, the United Arab Emirates, Sweden, Australia, the USA and the UK (Dudić *et al.* 2024; Rostami *et al.* 2015; Qazi *et al.* 2021). A recognized relationship has been confirmed between undertaking risk management processes and construction project success (Banaitiene and Banaitis 2016). Hence risk management issues covering generic construction projects have been extensively covered in several previous research.

However, significant research gaps exist in the interplay of risk management and sustainable construction activities worldwide and the Zimbabwean context (Moyo and Chigara 2022). Zhao, (2024) pointed out that research in risk management has become skewed towards specialised facets such as sustainable construction projects. Furthermore, studies (Nobanee *et al.* 2021; Schulte and Hallstedt 2017) have revealed challenges of integrating risk management and sustainability into construction projects. The inherent risky characteristic of sustainable construction has been found to expose project operations to time, cost, quality, and competition challenges (Kibert *et al.* 2016; Martinelli and Milosevic 2016).

The construction landscape in Zimbabwe reflects these global trends, with inherent risks hindering project progression leading to a scarcity of successful projects (Nyoni and Bonga 2017). While previous research has shed light on various aspects of risk management (Bagenda and Ndevu 2023; El-Sayegh *et al.* 2021; Qazi *et al.* 2021) on the construction projects, significant gaps remain in the Zimbabwean context (Moyo and Chigara 2022). Studies undertaken in Zimbabwe focused on sustainable construction indicators for construction projects, sustainable materials, and sustainable buildings (Moyo *et al.* 2024; Tanyanyiwa and Juba 2018). These studies discovered environmental protection and reporting as the significant indicators for benchmarking sustainable construction. Other studies focused on building sustainability from the planning perspective (Chirisa 2014). There is a dearth of studies regarding the impact of risk management practices on construction projects in Zimbabwe particularly in an era where sustainability concerns are now mandatory for all nations subscribing to United Nations Sustainability Goals. Therefore, this study sought to address the identified gaps by providing empirical insights that will justify the adoption of risk management on sustainable construction projects in Zimbabwe.

2 SUSTAINABLE CONSTRUCTION CONCEPT

Sustainable construction is defined as the responsible management of a healthy built environment, by minimising environmental impact while advancing social and economic sustainability (UNEP 2011). Various researchers have embarked on studies on sustainable construction. Haapio and Viitaniemi (2008) underscore the significance of life cycle thinking considering the environmental impacts of buildings. Eriksson, Larsson and Pesämaa (2017) emphasize the necessity of a proactive approach to address the unique challenges posed by sustainability initiatives on construction projects as part of the broader risk management process.

Sustainable construction projects prioritize environmental preservation, long-term viability, and social responsibility, unlike conventional projects with a target on short-term cost efficiency. Hence sustainable construction practices improve durability, equitable developmental practices and reduce ecological footprint throughout the project lifecycle (Okogwu *et al.* 2023).

2.1 *Risk management in sustainable construction projects*

Risk management is a linchpin in sustainable construction projects, offering a systematic process to identify and mitigate potential risks (Eriksson *et al.* 2017). Few studies have looked at risk management on sustainable construction projects (Apine and Wåhlin 2016;

Marandi Alamdari *et al.* 2023; Schulte and Hallstedt 2017). Risks identified on sustainable construction include supplier malperformance, non-availability of sustainable materials, culture differences and moral hazard. The identified risks imply that there needs to be a study focusing on these risks to improve the management of these risks. Lees (2012) confirms the need for specialized attention to construction risk management on sustainable projects. The inherent complexity and uncertainty of sustainable projects, compounded by the integration of green materials and innovative technologies, necessitate attention to risk management. Various risks have been identified in sustainable construction projects. Risks include shortages of funding, unrealistic schedules, design change, and poor definition of scope (El-Sayegh *et al.* 2021; Qazi *et al.* 2021).

2.2 *Key risk management strategies and tools*

Various risk management strategies and frameworks have been employed globally to navigate the intricacies of sustainable construction projects. These include internationally recognized standards such as ISO 31000, the Project Management Institute's Project Risk Management Framework, and the Construction Industry Institute's Project Risk Management Process (Shen *et al.* 2021). Risks have remained prevalent, particularly on sustainable construction projects with the advent of these complex frameworks and strategies. Risks that have been experienced include shortages of funding, unrealistic schedules, design change, and poor definition of scope (El-Sayegh *et al.* 2021; Qazi *et al.* 2021), financial risks, environmental degradation, social disruptions, and technological uncertainties (Adenle *et al.* 2017).

In response to the risks previously mentioned, risk management tools have been proposed and used offering different levels of effectiveness. Risk management tools include SWOT analysis, Life cycle assessment, risk mapping, decision tree analysis, HAZOP studies (Keeney and Raiffa 1993; Schwartz 1991). SWOT analysis facilitates a comprehensive overview of negative threats to project dynamics, whereas Life Cycle Assessment (LCA) evaluates environmental impacts throughout a project's life cycle. Despite, the use of these risk tools, negative impacts from risks have continued to be manifested as an inherent characteristic of construction projects that require constant monitoring and review. While sustainable construction projects offer immense potential for environmental and social benefits, none-consideration of risk management poses significant challenges. Effective risk management is essential to address these challenges and ensure project success.

2.3 *Implications of risk management on sustainable construction projects*

Effective risk management practices wield substantial influence on sustainable construction projects in Zimbabwe and beyond, with far-reaching implications for project outcomes and stakeholder satisfaction (Moyo and Chigara 2022). Further, meticulous risk management on construction projects can pre-emptively address common industry pitfalls such as project delays, cost overruns, and quality compromises. Furthermore, risk identification and management also foster resilience against the unique constraints prevalent in Zimbabwe's sustainable construction landscape (Madanhire *et al.* 2020).

Effective risk management also engenders stakeholder satisfaction (Nhamo *et al.* 2020). Risk management strategies can stimulate a harmonious project environment conducive to success (Love *et al.* 2018). Improved communication, collaboration, and cooperation stemming from enhanced stakeholder satisfaction can facilitate smoother project execution, alleviate conflicts, and bolster the project's reputation among stakeholders (Akintoye *et al.* 2015; Faniran *et al.* 2017). Additionally, risk management practices elevate the project's standing, by enhancing its appeal to stakeholders and bolstering its competitive edge (Ji *et al.* 2021).

Robust risk management practices serve as bulwarks against legal and financial vulnerabilities inherent in sustainable construction projects, safeguarding project stakeholders from regulatory non-compliance penalties and financial setbacks (Zhang *et al.* 2018). Consequently, risk management practices fortify project resilience and financial stability (Owusu-Manu *et al.* 2018).

Effective risk management improves safety and environmental outcomes, crucial imperatives in sustainable construction projects (Hong *et al.* 2019; Rostami *et al.* 2015). Risk management practices therefore enhance the success of sustainable construction projects by considering safety and environmental outcomes which are pivotal in social and environmental sustainability dimensions (Hong *et al.* 2019). Therefore, risk management frameworks and tools tailored to local contexts enable construction project managers to navigate the complexities of sustainable construction with confidence, driving positive change and sustainable development.

3 RESEARCH METHODOLOGY

A quantitative approach was adopted for the study using a questionnaire survey instrument administered via an online platform to all 90 civil engineering contractors registered with the Construction Industry Federation of Zimbabwe (CIFOZ) in categories A and B. This survey design allowed the extraction of a snapshot of the current landscape and implication of risk management practices in construction projects in Zimbabwe. Bryman (2016) argues that quantitative methods allow the systematic collection and analysis of numerical data. Questionnaires were also adopted due to their cost-effectiveness and expediency in collecting quantitative data (Creswell 2013). Studies in risk management research have utilized questionnaires (Dudić *et al.* 2024; Rostami *et al.* 2015) as a data collection tool.

The questionnaire consisted of 3 sections. Section A probed the demographic information of respondents, with Section B asking the respondents about their perception of the utilisation of risk management practices on sustainable construction projects, while Section C probed the implication of risk management on sustainable construction projects in Zimbabwe. A Cronbach alpha reliability test was conducted to assess the stability and consistency of the questionnaire in measuring the utilisation and implication of risk management practices on construction projects. The collected data were tabulated and analysed using mean scores, and Pearson correlation in a bid to determine the implication of risk management practices in Zimbabwe.

4 RESULTS

The Cronbach alpha test yielded coefficients ranging from 0.77 to 0.85 across all the questionnaire sections. According to Ursachi *et al.* (2015), the overall reliability coefficient of 0.83 indicates robustness in capturing intended constructs. Thus, the Cronbach coefficients obtained indicated that the questionnaire could be used as a reliable instrument in the study. This section presents the demographic information of the respondents, tools used in risk management and the implications of risk management on sustainable construction projects.

4.1 *Response rate*

Of the 90 questionnaires that were distributed to the selected respondents, 84 were returned by the respondents. After cleaning of data, 79 questionnaires were deemed usable, constituting an 88% response rate. This response rate surpasses the normative minimum response rate of 70%, and is considered significant for analysis (Saunders 2016).

4.2 *Demographic information of respondents*

Table 1 presents the respondents' demographic information regarding educational levels and work experience.

Table 1. Demographic information of respondents.

Category		Frequency	Percentage
Gender	Male	65	82
	Female	14	18
	Total	79	100
Work experience			
	< 5 years	20	26
	5-10 years	18	23
	11-15 years	15	19
	16-20 years	13	16
	> 20 years	13	16
	Total	79	100
Education qualification			
	National certificate	10	13
	Diploma	15	19
	Honour's degree	30	38
	Master's degree	21	27
	PhD	3	3
	Total	79	100

As shown in Table 1, the results indicate that most of the respondents were male (82%), while the female respondents constituted about 18%, hence signifying male dominance within the civil construction sector. Additionally, 26% of the respondents had less than 5 years of experience, 23% had 6 to 10 years of experience, and 19% of the respondents had 11 to 15 years of experience. The results also show that 16% of the respondents had an experience of 16 to 20 years and above 20 years respectively. Considering that 75% (majority) of respondents, had more than 6 years' experience, it meant that the collected data possessed deep insights that are required to contribute towards the utilisation and implication of risk management practices on sustainable construction projects in Zimbabwe.

4.3 *Utilisation of risk management practices in sustainable construction projects*

The study sought to assess the level of implementation of risk management practices on sustainable construction projects. Thus, the respondents were asked to rate the extent of use of twelve distinct risk management tools, spanning from traditional tools such as checklists and risk registers to more advanced techniques like Monte Carlo simulation and Life Cycle Assessment (LCA), using a 5-point Likert scale, ranging from 1 – very low extent, 2-low extent, 3-medium extent, 4-high extent and 5 – very high extent. Table 2 shows the results of the study.

Table 2 shows that the mean of the risk management tools utilised in Zimbabwe ranged from 4.45 indicating a high extent of utilization to 3.39 indicating a medium extent of utilization. HAZOP studies had a mean rating of 4.45, Scenario Management 4.36, and Decision Tree Analysis 4.21, Benchmarking with a mean score of 4.16 and Checklists and Risk Registers with a mean score of 4.16. Other tools such as quantitative risk assessment, life cycle mapping and earned value management are used to a medium extent within the Zimbabwean context as evidenced by mean ratings of 3.39, 3.79 and 3.96 respectively. Table 2 also shows a negative kurtosis for all the risk management tools that were being tested. Negative kurtosis shows that there were few variances in the data that was collected, thus collected data was concentrated on the mean.

Table 2. Usage of risk management practices.

Risk Management Tool	Mean Score	Kurtosis	Rank
Hazard and Operability (HAZOP) Studies	4.45	−0.52	1
Scenario Management	4.36	−0.57	2
Decision Tree Analysis	4.21	−0.68	3
Benchmarking	4.16	−0.72	4
Checklists and Risk Registers	4.16	−0.74	5
Monte Carlo Simulation	4.11	−0.81	6
Risk Mapping	4.06	−0.87	7
SWOT Analysis	4.03	−0.92	8
Failure Mode and effects analysis (FMEA)	3.97	−0.88	9
Earned value Management (EVM)	3.96	−0.82	10
Life Cycle mapping (LCM)	3.79	−0.73	11
Quantitative Risk Assessment	3.39	−0.66	12

4.4 *Implications of risk management on sustainable construction projects*

The study also explored the implications of risk management practices implemented in the Zimbabwean context on sustainable construction projects. Thus, the respondents were asked to rate the extent to which implications of risk management identified from existing literature were being experienced on sustainable construction projects, using a 5-point Likert scale, where 1 represented a very low frequency and 5 very high frequency. Table 3 summarises the results of the study. From Table 3, the results show that most respondents highly rated the frequency of occurrence of the implication of risk management practices, as indicated by mean scores ranging from 4.35 to 4.57. The highly rated implication was effective consideration of stakeholder expectations with a mean score of 4.57, whilst increased stakeholder satisfaction was lowly rated with a mean frequency of 4.35.

Table 3. Implications of risk management on sustainable construction projects.

	Level of Agreement		
Implication of Risk Management Practices on Sustainable Construction Projects	Mean Score	Kurtosis	Rank
Stakeholder expectations are effectively considered.	4.57	−0.60	1
Adequately address external factors.	4.54	−0.59	2
Influence broader business goals.	4.53	−0.57	3
Contributes significantly to effective checking of time, quality, and cost of sustainable construction projects.	4.51	−0.55	4
Positively influences sustainable project outcomes.	4.51	−0.55	5
Influence project performance	4.50	−0.54	6
Reduced legal and financial risks associated with sustainable construction projects.	4.48	−0.52	7
Enhanced the reputation of sustainable construction projects.	4.43	−0.51	8
Improved safety and environmental outcomes in sustainable construction projects.	4.37	−0.49	9
Increased stakeholder satisfaction in sustainable construction projects.	4.35	−0.50	10

Following the ranking of the extent to which these implications are experienced on construction projects, the study also established the correlation between risk management techniques and the implications of risk management on sustainable construction projects. A Pearson Product correlation moment coefficient of 0.8841 was obtained. This shows that there is a strong positive relationship between risk management tools and the implications of risk management on sustainable construction projects (Liu *et al.* 2019).

5 DISCUSSION OF RESULTS

Firstly, the study has shown that construction projects have been dominated by the male gender as shown by 82% of the respondents being male. This finding deviates from one of the United Nations Sustainability Goals which advocates for gender equality. The study revealed that risk management tools are utilised at varying degrees within the Zimbabwean context. The findings indicated the predominant risk management tools used on sustainable construction projects as HAZOP studies, scenario management, decision tree analysis, benchmarking and checklists and risk registers. Risk management tools found to be dominant in the study are consistent with extant literature (Lees 2012; Keeney and Raiffa 1993; Schwartz 1991) which highlight that hazard studies, decision tree analysis and scenario analysis are widely used globally. Dominance of HAZOP studies, scenario management, and risk registers are essential in managing risks on sustainable projects. HAZOP studies safeguard the socially sustainable construction project dimension while the decision tree analysis, benchmarking and checklists work well in safeguarding the economic and environmentally sustainable construction dimensions. The use of these tools is likely to ensure construction project success as viewed from a sustainability position.

Some risk management tools such as life cycle assessment, SWOT analysis and risk mapping were found to be moderately implemented. These results contradict the views of Lees (2012). Non-dominance of these techniques indicates a deficiency in the risk management process undertaken to ensure the success of sustainable projects. Lack of use of life cycle assessment indicates that projects perform poorly in life cycle costs thereby hindering the economic sustainability dimension of construction projects. Non-consideration of life cycle costs in risk management suggests a lack of inclusivity in the interests of future generations in line with the sustainability philosophy. Hence, life cycle costs should be adopted to enhance the sustainability of construction projects in Zimbabwe.

The study further found that the identified risk management tools pose several implications for sustainable construction projects in Zimbabwe. Risk management practices in Zimbabwe exhibit 10 major implications on sustainable construction projects as shown by the results of this study Though some of these stated implications may apply to non-sustainable construction projects; this study argues that most of these implications retell the story that is experienced where risk management is undertaken on sustainable construction projects. Risk management for sustainable and non-sustainable projects does not differ, distinction comes in the types and extent of risks experienced on these projects. These findings are consistent with existing literature (Love *et al.* 2018; Nhamo *et al.* 2020). For instance, Nhamo *et al.* opine that effective risk management lead to stakeholders' satisfaction. As argued by Chen and others, stakeholders' satisfaction engenders project success due to the effective collaboration of key stakeholders. Moreover, Akintoye *et al.* (2015) and Faniran *et al.* (2017) posit that stakeholder satisfaction can mitigate conflicts and promote a project's reputation and overall project success. Most conventional projects where risk management is not considered, experience some problems such as appointing inexperienced contractors, unforeseen ground conditions, project complexity conflict between contracting parties and deliberate underestimation of project costs (Hove 2016; Moyo and Chigara 2022).

6 CONCLUSION

Based on the study's results, the major implications of risk management practices on sustainable construction projects include stakeholders' satisfaction which is a critical ingredient to the project's success. Curbing external factors, positive influence on business goals, and effective checking of time, quality, and cost of sustainable construction projects are some of the notable implications of risk management practices. The identified implications emanated from the use of risk management tools such as HAZOP studies, scenario management, decision tree analysis, benchmarking, checklists, and risk registers. These implications attest to the importance of risk management practices on sustainable projects in Zimbabwe. Therefore, the study concludes that these stated implications may apply to both sustainable and non-sustainable construction projects, though most of these implications equally apply to risk management undertaken on sustainable construction projects. Hence, the study recommends all key stakeholders in the construction industry improve the usage of various risk management tools to improve the delivery of sustainable projects in Zimbabwe and similar contexts. There is a need to enhance awareness of some of the risk management tools that are lowly utilised in Zimbabwe and yet their prominence is widely supported by several scholars elsewhere. While context is pivotal in selecting the appropriate risk management tool, it is indisputable that the lethargic usage of some of the tools is attributed to a lack of knowledge among some of the stakeholders. Therefore, the results of the study could assist policymakers and other key stakeholders in developing mechanisms to improve the implementation of risk management tools that promote the effective delivery of sustainable construction projects in Zimbabwe and similar contexts in Sub-Saharan Africa. Despite the generalisability of the findings being limited by geographic elimination and the small sample size, the results provide valuable insights into the importance and impact of risk management practices on sustainable construction projects. Future studies could therefore extend the study to both building and civil contractors including construction professionals in Zimbabwe and or other countries within the Global South.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Two decades of (ISO) and (TQM) in the Zambian construction industry: Lessons learnt

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ABSTRACT: ISO and TQM systems were introduced to the Zambian construction industry in the late 1990s. One of the projects implementing these two quality systems was the COSAC project which involved the development of a mine processing plant by ISO and TQM foreign contractors. It was expected that ISO and TQM quality standards-based skills would be transferred to the Zambian contractors working with quality certified foreign contractors thereafter. However, from 1998 to 2022, it is unknown if these quality management skills have been transferred to Zambia contractors that have worked with quality certified contractors. This study used four cases of projects undertaken by quality certified foreign contractors to establish levels of skills transferred and lessons learnt by local Zambian contractors derived from working with these foreign contractors. Through questionnaires and interviews, the study revealed low levels of awareness and no adoption of quality standards among Zambian local contractors.

Keywords: International Standard Organization (ISO), Total Quality Management (TQM), construction, quality, contractors, Zambia

1 INTRODUCTION

Quality management as a comprehensive and structured approach that emphasizes continuous improvement in all stages of operations with focus on excellent performance of tasks. Further, it involves and empowers employees at all levels of an organisation Ephantus (2015). Quality management has been applied by different organisations as a strategy to resolve many issues that include but not limited to customer dissatisfaction, wastage of materials that result in cost overruns among others. A study by Sharif (2005) emphasised that quality management is of great importance and motivates organisations to adopt International Organisation for Standardisation (ISO) 9000 quality standards and Total Quality Management (TQM) certification. Muleya and Zulu (2015), state that quality management is a systematic way of guaranteeing that all activities within an organisation are carried out as planned and produces positive results that satisfy both internal and external stakeholders, this is consistent with some research findings by Sharif (2005), on the importance of application of quality management in the construction industry just like other industries.

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2 BACKGROUND TO THE STUDY

Zambia had experienced an average growth of between 4.2 and 4.7 percent in 2019/2020 and 2020/2021, respectively in the construction industry that seems to have positively influenced national economic growth (Nyaywa 2020). However, the construction industry in Zambia is characterised by quality shortfalls, cost and time overruns as well as project abandonment (Kaliba *et al.* 2009). The 2021 Zambia National Assembly Committee Report on Transport, Works and Supply indicated that Zambia requires a sustainable construction industry with a collection of contractors that have the ability to participate competitively and undertake construction works effectively in order to meet current and future requirements of different clients and the industry. It is clear that the economic liberalisation in Zambia has attracted both local and international investment in the construction industry (Siame 2015). However, most of the high value projects amounting to between 80% and 90% by contract sum have been undertaken by foreign construction companies mainly because of deficiencies in capacity among indigenous companies (Mambwe *et al.* 2020). The level of participation by local contractors in the construction sector has remained low and it was mostly confined to low value and small works contracts of up to 20% of the contract value. Moreover, statistics from the National Council for Construction (NCC) equally show very low participation of indigenous companies in the construction sector because most of the high value projects are delivered by foreign construction companies because of deficiencies in capacity of indigenous companies as evidenced by their inability to demonstrate financial, knowledge as well as ownership of key machinery required for construction works (Tembo *et al.* 2021). Zambia's construction industry has embraced the ISO 9000 quality standard and TQM since 1998 as an initiative to resolve quality problems in the industry (Muleya and Zulu 2015). Many projects particularly in the mining sector gave been delivered by ISO certified foreign contractors motivated by ISO certified mining house investors who demanded that main contractors and consultants should be ISO or TQM accredited (*ibid*). In Zambia, the COSAC project was one of the first projects to introduce ISO quality standards and TQM in the construction industry in September 1998 through a company called Anglovaal mining (AVMIN) which entered into a development agreement with Zambia Consolidated Copper Mines Investment Holdings (ZCCM-IH) and the Zambian Government (Munnik *et al.* 2003). The construction workforce was highest at 1,475 in November 2000 of which 70% were Zambian nationals. A detailed study of the project conducted by Muleya (2000) revealed that the main consultant and the main contractors in the joint venture project were ISO 9001 and ISO 9002 certified respectively at that time. This resulted in the high-quality delivery of the project in terms of time, quality and safety of the project (Hoscroft 2002). It was deemed that ISO 9000 quality standards and TQM based skills would be transferred to the Zambian contractors in order to improve their delivery methods that would eventually trickle down to other contractors. More than two decades after the ISO and TQM driven projects were introduced in the Zambian construction industry, there was no information to indicate the magnitude of skills transferred to Zambia contractors in terms of quality management based on lessons learnt from main contractors that are either ISO 9000 or TQM certified. Additionally, there was lack of improved quality performance as evidenced by poor performance of local contractors justified by an increased number of poorly delivered projects. The aim of this study was to establish the levels of skills transfer, awareness of ISO and TQM tools and certification, and establish lessons learnt by local Zambian contractors derived from working with foreign contractors that had quality accreditation since 1998. The study provides an audit and analysis of the local contractors growth in the area of quality management and certification which is one of the new demands made by clients especially int the private sector.

3 LITERATURE REVIEW

In the modern industrial world today, quality and continuous quality improvement has become important themes used by many organisations to build a competitive strategy to improve the quality of products and services. Salaheldin and Alphy, (2008) observed that trends in the construction market were characterised by dynamic and ever-changing customer demands and expectations. The ISO 9000 series and Total Quality Management form part of the universal framework for quality management and has continued to provide solutions to the changing expectations and demands of the clients in the construction industry like many other industries (Raweni 2018).

3.1 *Definitions of quality and associated principles*

The word quality conveys ideas of elegance, luxury, craftsmanship among others when it is used (Sharif 2005). Hoyle (2017) indicated that quality requirements involve availability, reliability, delivery, maintainability and cost effectiveness. The general perception of quality has changed over time from being measured by, or assumed to, result from attaining some allowable level of defects to meeting customer requirements and even do better than expected (Withers and Ebrahimpour 2001). Many quality management authors scholars have defined quality differently, Deming (1986) defines quality, as "Quality should be aimed at the needs of the customer, present and future", whereas Ho and Fung (1994) indicated that Total Quality Management is "a way of managing to improve the effectiveness, flexibility and competitiveness of a business as a whole. It is also a method of removing waste by involving everyone in the way things are done.

3.2 *Quality control in construction industry*

In the construction industry, quality control is defined as the ability to monitor specific project result to determine their compliance with relevant quality standards as well as establishing ways of removing causes of dissatisfaction. According to ISO (8402), quality control comprises of the operational procedures and activities required to meet quality criteria. Project Quality Control functions include project quality processes, project inspection and test plans, as well as product/service characteristic inspection and measurement (Zeng 2000). Inspection, control charts, pareto diagrams, statistical sampling, flowcharting, and trend analysis are examples of quality management tools. This activity produces primarily acceptance/reject/rework decisions, test documentation, and process adjustments.

3.3 *Quality assurance in the construction industry*

Quality assurance is described as the process of systematically reviewing overall project performance in order to obtain confidence that the project will fulfil the required quality requirements (Shaikh and Sohu 2020). One of the inputs used in quality assurance is the project quality method. It is not an afterthought to a process. Project quality procedures, quality control measurement results, project quality documentation, quality management plan, and operational definitions are the inputs to the project quality assurance function (Enshassi and Ayyash 2014). Quality planning tools and quality audits are among the tools and techniques used in this role, and the outcome is a quality improvement programme that defines and improves updates to project quality processes (Nyaywa 2020).

3.4 *International Standard Organisation (ISO)*

International Organisation for Standardisation (ISO) was founded in 1946 in Geneva, Switzerland where the capital is still based (Majstorović *et al.* 2015). The ISO quality standards are utilised in various industries construction inclusive for quality improvement (Hajstorovic *et al.* 2015). Ever since its introduction, the number of organisations with ISO 9000 certification over the world has increased in developed and developing countries (Creswell and Poth 2016). Additionally, the ISO 9000 family of standards has been utilised by many industries and countries in the world and as of 2022 its new model was ISO 9001: 2015 with particular characteristics for continuous improvement (Raweni 2018). Members include full members, correspondent members and subscriber members (ISO 9000). The ISO quality standard family has evolved in content and application due to changes in the markets as they are developed based on the demands of the market to not only facilitate international trade but also demonstrate capability and give customers confidence by satisfying their needs and expectations through continual improvement (ISO 9000). In the construction industry, all efforts of this ISO standard edition aim at increasing organisations' awareness of its duties and commitments in fulfilling the needs and expectations of the customers and interested parties (Thompson *et al.* 2016). It contains elements such as top management responsibilities, context of organisation, continual improvement, process management among others that are applicable to the construction industry (Nyaywa 2020).

Rewane (2018) outlined the seven principles as shown in Figure 1 of ISO 9001: 2015 as follows: meeting customer requirements, leadership, engagement of people, process approach, improvement in decision-making, evidence-based decision-making and relationship management. The ISO 9004: 2018 quality management system was developed to cancel and replace the third edition (ISO 9004: 2009) which was technically revised to enable organisations such as those in construction industry to achieve sustained success in a complex, demanding and ever-changing environment. The main changes were basically to align it with the concepts and technologies of ISO 9000: 2015 and ISO 9001: 2015 as well as to focus on the concepts of quality of the organisation and its identity.

Figure 1. The changing purpose in the ISO family. Source: (Hoyle 2017).

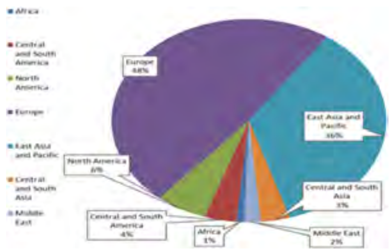

Figure 2. The distribution of the total number of ISO 90001 certifications in the period 1993-2015 in seven regions of the world, Source: ISO survey 2015.

Figure 2 shows that Africa is at the bottom in terms of getting ISO certification at 1% which explains the low level of awareness and certifications in Africa, Zambia inclusive against 48% in Europe. This further explains the low levels of quality delivery by African firms mainly due to unacceptable levels of non-conformance in quality related matters.

3.5 *Total Quality Management (TQM)*

Quality management skills transfer and knowledge acquisition is one of the most reliable strategies for empowering the developing contractors especially in the construction industry because this can sustain their businesses (Sharif 2005). Kulemeka *et al.* (2015) and Kikwasi (2011) explain that lack of skills in the construction industry and poor quality have been linked to training efforts especially among contractors. ISO and TQM skills transfer is a strategy that construction companies use to adapt to the market quality needs that are dynamic. Continuous employee development and training in quality related matters enable companies to address construction project shortcomings especially when faced with several challenges such as lack of logistics and shortage of skilled labour requirements for constructing and operating facilities. Training was highlighted as one of the most crucial components in the effective implementation of TQM by in a study carried out by Jamali *et al.* (2010). TQM implementation need enough applicable staff skills and understanding of quality, which can only be obtained via ongoing training. Training enables employees to participate in continuous improvement projects, which are critical in TQM implementation (Oluwatoyin and Oluseun 2008). Employees at all levels must embrace quality education and training because it helps them comprehend quality management efforts and their responsibilities in TQM implementation (Arshida and Agil 2012). An empirical study on essential TQM elements in Palestinian firms done by Hoyle (2017) revealed a strong association between staff training and successful TQM implementation.

4 RESEARCH METHODOLOGY

4.1 *Data collection*

In this research, a case study method was used through four (4) independent projects on the Copperbelt Province of Zambia undertaken by foreign contractors that are ISO and TQM certified to establish the levels of skills transfer, awareness of quality management tools and certification, as well as lessons learnt by local Zambian contractors derived from working with foreign contractors that are ISO and TQM quality assurance and control accredited. 15 Zambian local subcontractors engaged by foreign main contractors that are ISO and TQM certified. This method was deemed suitable approach for this study because it enabled an all-inclusive and a detailed investigation on cases targeted. This approach is supported by Kenneth and Bruce (2018) who states that in investigative studies like this one, case studies become useful as they enable collection of comprehensive data. In view of the aforementioned, this study used a mixed method approach to maximise the collection of both qualitative and quantitative data for the study. It further utilised a descriptive and expressive case study approach that was examined and analysed through quantitative and qualitative methods. Ethridge (2004) indicated that descriptive research is used to describe characteristics and/or behaviour of sample population. Table 1 shows the respondents and the associated numbers that were targeted for data collection.

Table 1. Respondent details to the research.

S/N	Organisation/Individuals	Respondents	No. of Respondents by category
1	Local Contractors (Grade 1 to 6)	Employees	15
2	Foreign Contractors (Grade 1 to 6)	Employees	4
3	National Council for Construction	Regional Manager (Northern Region)	1
4	Clients (Private individuals and corporate entities)	Employees	4
Total			24

4.2 *Data analysis*

This research adopted the Likert Scaling instrument to collect quantitative data from the questionnaires According to Kothari (2004), the Likert Scale offers a one-dimensional summated scale from which respondents choose an option that best fit their opinion. The data was analysed by using the descriptive statistical technique. The scale was based on the assumption that each statement had equal importance or weight in terms of reflecting an attitude towards the issues in the question. The recorded data was coded for accuracy into SPSS and Microsoft Excel. Tables, graphs and charts were used to draw meaning from the descriptive data based on the research objectives and questions. The mean analysis was employed to rank the criteria in accordance with their value on the practised or/ shared ISO and TQM skills as well as lessons learnt from the ISO and TQM certified foreign contractors, however, these results were nor reported as they were mainly based on the practices that are similar to approved quality standards. Only descriptive statistics were reported due to the low population and sample available. Qualitative data was collected through Interviews with four (04) ISO and TQM certified foreign contractors operating on the four selected cases. All the personnel interviewed were in top management. It was also revealed that all four companies interacted with were in grade one (1) of the National Council for Construction (NCC) registration category, and were undertaking civil works, building works, mining services and mechanical engineering. In terms of experience, they had all over five years and some had in excess of 20 years of experience in Zambian Construction Industry. This made them more qualified and eligible to provide information on the existence of ISO and TQM in construction industry under the period of review. Thematic analysis was used to analyse qualitative data obtained from interviews caried out with employers. Themes were developed from the interviews responses and analysed based on the research objectives. Explanation of each theme was done on level of skills received and lessons learnt by local Zambian contractors derived from working with mainly foreign contractors that are quality assurance and control accredited and measure the level of awareness on quality standard certification among Zambian local contractors.

5 RESULTS AND DISCUSSION

This section presents results obtained based on questionnaires and interview data. Figure 3 shows the positions of the respondents from the 15 local subcontractors. Data indicates that there was an indication that all the respondents were likely to have sufficient levels of knowledge expected to respond to the subject at hand considering their positions providing credibility of the data obtained from the local subcontractors.

Figure 3. Respondents roles in the organizations.

Table 2 shows that all the local contractor respondents had valid experience to participate in the research and provide sufficient information required for analysis. The experience of working with foreign quality certified contractor ranged from 1 to 15 years which provided reliable responses

Further, all the respondents' companies were neither certified for ISO nor TQM despite having worked with certified contractor between 1 to 15 years. Figure 4 shows that respondents had little or no knowledge about the ISO and TQM systems. This is an

Table 2. Experience with foreign contractors that are ISO and TQM certified.

Years of experience	No of respondents
1-5	5
6-10	9
11-15	1
Total	15

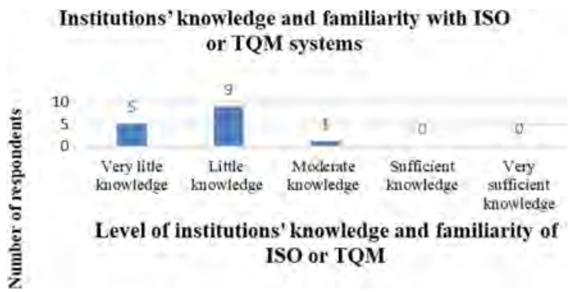

Figure 4. Level of institutions knowledge and familiarity of ISO or TQM.

indication that despite many years of ISO and TQM existence in the Zambian construction industry, local contractors have not adopted or taken interest to learn about the ISO and TQM skills. awareness on ISO and TQM certification among Zambia local contractors putting them at risk of being less competitive ((Arshida and Agil 2012).

This implies that despite the presence of ISO and TQM certified foreign contractors, the Zambian local contractors still had less knowledge on ISO and TQM certifications as shown in Table 3. These results were similar to those for having quality dedicated expertise in the organisations.

Table 3. Levels of awareness on ISO and TQM certification among Zambia local contractors.

Category	Responses
Extremely low	7
Low	8
Slightly low	0
High	0
Extremely low	0
Total	15

Only two out of thirteen local contractors operated with an established quality policy that promotes ISO and TQM quality standards while thirteen did not. Further the two local contractors had registered some kind of informal training in the past five years as indicated in Table 4.

Thematic analysis of selected results in Table 5 revealed that there is no time and platform to train local contractors on quality management apart from exposure to observing the certified contractors on site. The results also reveal that clients are slowly moving into the

Table 4. Local contractors' quality policy that also promotes ISO or TQM skills transfer.

Category	Responses
Quality policy present	2
Quality policy not present	13
Total	15

Table 5. Thematic analysis.

No.	Theme	Feedback (Verbatim)	Analysis
(a)	**Awareness** on ISO and TQM certification among local contractors	*… .there were low awareness of ISO and TQM certification and tools, most of local contractors had not even known its value to the construction industry. the only focus they had was on occupation health and safety of employees forgetting all others standards… …*	The results are consistent with quantitative results on low awareness of standards despite being in existence for more than two decades. Results revealed that only health and safety standards were practiced while neglecting quality standards.
(b)	Contractual **requirement**	*… ..yes it was a contractual requirement as demanded for by the client, to some extent this made us beat other bidders in the bidding process … ..*	There is evidence that major private clients demanded that the main contractor must be ISO or TQM certified. This is one of the major reasons that foreign contractors have been awarded large contracts due compliance
(c)	**Skills transfer** and key skills shared	*… .due to lack of deliberate initiatives from the company to transfer ISO and TQM skills to the local contractors, the only way the local contractors were learning was through informal routes*	There were low efforts in skills sharing as three out of four companies had not shared any skills Additionally, there were no sufficient deliberate initiatives for ISO and TQM skills transfer.
(d)	Quality **Policy and certification**	*… … yes there was a deliberate quality policy and also a quality management department that fostered the implementation of ISO in construction activities and got audited every after a particular period of time*	All the foreign contractors' companies had deliberate quality policies. The presence of quality policy influenced the application of ISO and TQM and hiring of certified firms to do the construction works. There was 100% commitment to quality efforts by the foreign contractors as it was seen from their certifications.

space of demanding that main contractors must be ISO or TQM certified which may deny Zambian local contractors from participating in large contracts as they can't provide the needed confidence of quality delivery of the projects.(Shaikh and Sohu 2020). It is clear that few or no lessons have been learnt by Zambian local contractors despite working with certified contractors for many years, a situation that requires serious review if the local contractors are to build capacity to compete for jobs floated by ISO and TQM accredited clients particularly in the private sector.

5 PRACTICAL IMPLICATIONS

The study clearly indicates that little and many occasions no lessons were learnt by Zambian local contractors from quality certified foreign contractors despite the quality systems being around in the construction industry for over two decades. The implications are that local contractors will not compete with quality certified contractors thereby stagnating their growth. With the number of clients demanding quality certification increasing, many Zambian contractors risk losing many contractors to foreign quality certified contractors thereby making local contractor capacity weak and limited as indicated by (Shaikh and Sohu 2020). The study further reveals that all clients that demand for quality certified contractor are in the private sector an indication that government has not made progress in raising the quality standard bar from within and without.

6 CONCLUSION

Quality training, policy adoption, certification and practice must be driven by the local contractors. The absence of quality certification which to a large extent reflects financial capacity of the firm has contributed to the hinderance by Zambian contractors from entering into the space of foreign working as main contractors on major projects in Zambia amounting to 90% by contract value. The study reveals that despite ISO and TQM standards being in existence for over twenty years in the construction industry since late 1990s, the local contractors have not grown enough to embrace quality policies and certification. From the study results, it is evident that little or no lessons have been learnt by Zambian local contractors from working with foreign certified contractors. This is evidenced by low levels of quality awareness and willingness to get certified or embrace practices that are ISO and TQM supported. It was expected that even without quality certification, the local contractors could learn from foreign quality certified contractors by adopting practices that were underpinned by quality policies and practices. It is of great concern that despite working with experts and experienced contractors that are driven by quality systems, no significant learning has taken place because awareness levels on ISO and TQM in the Zambian construction industry remain significantly low. With clients, particularly in the private sector becoming more demanding in terms of quality certification and accreditation, it is extremely important for Zambian local contractors to consider getting training in quality management and implementation even before getting certification. This route could even raise the participation capacity from the current 20% in public related projects. Organizations such as the National Council for Construction must derive ways of promotion and incentivizing local contractors' adoption of quality management practices that will enhance their capacity to compete for contracts floated by quality certified clients

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Theme 7: Sustainable construction materials

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

An effective repair strategy for low-cost housing: A condition-based analysis using KwaThema Township as a case study

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ABSTRACT: This paper presents a comprehensive analysis of repair strategies for low-cost housing in KwaThema Township, South Africa. The study conducts a thorough visual inspection of 30 houses, scrutinizing aspects such as foundations, floors, wall cracks, roofing, electricity, and plumbing. The primary objective is to comprehend the condition of low-cost housing structures in these areas and propose an inspection and repair approach for optimal maintenance. The methodology involved evaluating the severity and extent of defects, resulting in an average quality score rating between 45% and 60%. Lower scores correlate with higher remediation costs. The research contributes valuable insights into the condition of low-cost housing, offering suggestions for cost-effective and sustainable repair and maintenance strategies. By addressing crucial aspects of condition assessment, this paper contributes to building maintenance and management, providing a reference for policy-makers, housing developers, and maintenance professionals to enhance living conditions in low-income communities.

Keywords: Low-cost housing, repair strategy, condition-based analysis, maintenance strategies, sustainability

1 INTRODUCTION

In 2012, the Department of Human Settlement of South Africa reported that 2.7 million low-cost housing units were either incomplete, uninhabitable, or in need of repair, resulting in housing challenges in urban areas (Baur 2022). According to Le Roux, 2019, by fixing and completing these existing dwellings, the waiting time for low-income housing could be reduced by up to 26 years. This study develops a repair approach for low-cost housing using decision-making guidelines and artificial intelligence methods. Homeowners and municipalities can use this model to enhance their knowledge with advice on the sustainability of the housing sector. A case study conducted in KwaThema Township demonstrates the effectiveness of this model. Comparisons with strategies reveal that the proposed model offers valuable guidance to homeowners, the Department of Human Settlements, and the National Home Builders Registration Council (NHBRC) (Abbot *et al.* 2007).

1.1 *Context and justification*

This research addresses the pressing need for repair strategies in South Africa's low-cost housing sector. Due to limited resources, homeowners struggle to maintain their properties, leading to rapid deterioration and declining asset value. The aim of this study is to explore condition-based maintenance through economic life analysis and the identification of age-related defects to optimize maintenance efforts (Md Dahlan *et al.* 2019). Hence, a previous

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study Md Dahlan *et al.* 2020, demonstrated that repair strategies are practiced in other countries such as Malaysia.

1.2 *Research objectives*

The primary aim of this paper is to introduce a repair strategy aimed at enhancing low-cost houses to ensure that they continue to serve as shelters. According to Ingemarsdotter *et al.* 2021, this strategy was designed to tackle issues in low-cost houses, aiming to decrease maintenance requirements and expenses for homeowners. He also mentioned that a repair plan was developed by identifying problems in the low-cost housing sector. The methodology employed was a case study using an approach. The success of the strategy was assessed through discussions with professionals from the Built and Environment industry and homeowners, leading to a plan that could be implemented by workers. Rectifying these issues could also result in improvements that increase property value in many countries.

2 LITERATURE REVIEW

The condition of low-cost housing is crucial for the construction sector, as neglecting low-cost housing while focusing on high-end properties could result in the deterioration of homes and indicate a setback in existing housing strategies across the globe. According to Hernández-cruz *et al.* 2024, addressing the importance of maintaining respectability and conditions can help to prolong homeownership. It also contributes to sustaining the low-cost housing sector in the country. It is crucial to identify signs of distress and implement interventions to repair and maintain properties. This study focuses on establishing a framework of failure patterns in low-cost housing to facilitate the identification of repair and maintenance approaches for KwaThema Township in South Africa.

Various issues, such as substandard building materials, lack of expertise, and excessive use, often result in patterns that can be addressed with regulations or guidelines to prevent complications. This method helps pinpoint failure modes, thereby enabling the implementation of repair strategies (Chakwizira 2019). For instance, inadequate foundation construction and poor-quality building materials have been identified as challenges in low-cost housing developments (Pillay 2017). From the review of the existing literature, having a repair plan for housing is essential for enhancing living conditions in underprivileged areas. Previous cost-effective ways to repair low-income housing have shown that condition-based methods are essential for meeting maintenance requirements (Md Dahlan *et al.* 2019). Countries like South Africa, India, and Brazil have adopted this repair strategy. Additionally, this research emphasizes the significance of considering the socioeconomic factors influencing affordable housing repair strategies in various communities.

2.1 *Low-cost housing challenges*

In South Africa, low-cost housing mainly consists of brick structures, yet they fall short of meeting the growing population's housing needs. Recent developments cater to beneficiaries but are located further from city centres, on "free" serviced sites that the beneficiaries cannot afford to build on. As a result, such sites remain vacant (Md Dahlan *et al.* 2019). The maintenance of a dwelling is an important part of a building's life cycle. Continuous maintenance should be adopted to address defects, even though occupants may not feel a sense of ownership due to being renters. Rental agreements typically include maintenance responsibilities for both landlords and renters, but the extent of maintenance completed by each party may differ (Md Dahlan *et al.* 2019).

2.2 *Repair strategies for low-cost housing*

Typically, homeowners or their family members undertake home repairs at a time that suits their household's needs, with cost and convenience being factors when deciding when to make repairs. Repair plans often involve a stage in which repairs are postponed until the house is ready for occupancy, followed by deferred repair stages while the house is lived in. Initially, concerns about damage to the property may not be the priority during the preparation phase of moving. A detailed repair strategy is developed to prioritise addressing identified issues and working together with the homeowner to meet their specific requirements and limitations. It is crucial to pinpoint the root cause of damage before planning their fixes because simply repairing damages may not solve the underlying issue, potentially leading to recurring problems. The strategy could involve a phased approach with suggestions for long-term solutions, enabling homeowners to begin with repairs and tackle work as their finances permit (Sabela 2014).

3 METHODOLOGY

The study employed a mixed-methods approach, combining qualitative and quantitative data to provide a comprehensive understanding of the current condition of low-cost housing and identify effective repair strategies. Data were collected through visual inspections of the selected 30 low-cost houses in KwaThema Township focusing on three sections, Deep Level, Riverside, and Masimini, identified by the complaints of the inhabitants to the local Ekurhuleni Municipality due to the safety and integrity of the structure of the houses. An open-ended questionnaire was administered on a house-to-house basis to the occupants of the low-cost houses identified in assessing elements such as wall cracks (internal and external), foundation stability, roofing conditions, and electrical system proficiency. The results were captured on a Microsoft Excel score sheet for the computation of the quality indices. An online sample size calculator (https://www.calculator.net/sample-size-calculator.html? 2016) was used to create a random sample to determine sample size. The sample size required for this study was 28, thus the response rate was 95% confidence level with a 5% margin of error.

The questionnaire consisted of three sections; background information on respondents' details on repair and maintenance issues and causes of defects in the low-cost housing sector. A ranking scale was used for responses to building conditions, as outlined in Table 1, into 'excellent ', 'good',' fair',' poor', 'very poor' and the elements of the low-cost houses rated on a scale of 1-5. According to (Abbot *et al.* 2007), a five-point colour-coded rating system was developed and proved to be effective for conditional assessment.

Table 1. Definition of rating/condition of buildings. (Source: Education 2019).

Condition Assessment Rating Scale		
Rating	Condition	Description
5	Excellent	• Cracks are rarely visible in external masonry. • Hairline cracks less than 0,25 mm wide are classified as negligible. ***New Asset, No Maintenance***
4	Good	• Internal cracks that are easily filled. • Redecoration is probably required. • Recurrent cracks can be masked using suitable linings. • Cracks are not necessarily visible externally ***Regular Maintenance 5%***

(*continued*)

Table 1. Continued

Condition Assessment Rating Scale		
Rating	**Condition**	**Description**
3	Fair	• Cracks can be repaired, and a small amount of masonry may have to be replaced. • Articulation joints may have to be cut into some walls. Doors and windows sticking. • Rigid service pipes may fracture. Weather tightness is often impaired. Up to 10 mm gap between ceiling cornices and walls. ***(15-20%)***
2	Poor	• Extensive repair work includes breaking out and replacing sections of walls, especially over doors and windows, cutting of articulation joints in walls, and the construction of moisture trenches and apron slabs around the home, or the jacking of foundations depending on the type of soil movement. • Window and door frames are distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes are probably disrupted. Up to 20 mm gap between ceiling cornices and walls. ***Major Maintenance or Renewal (20-40%)***
1	Very Poor	• Major repair work is required, involving partial rebuilding and the above-mentioned repair techniques. Beams have loose bearing, walls tilt badly and require shoring. Windows were broken and distorted. • Danger of instability. ***Replace Required (>50%)***

To measure the quality indices of the different elements of the building, the score sheet contained visible elements of low-cost housing in Figure 1.

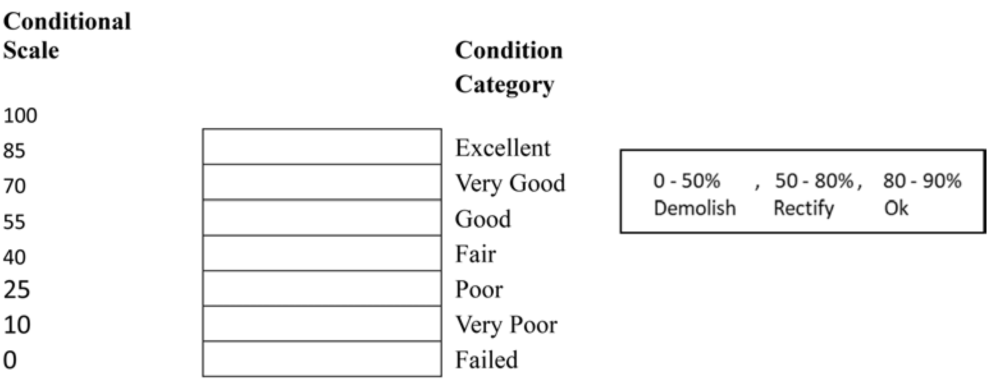

Figure 1. Condition Index Scale (Source: Uzarski, Hunter and Brotherson 1995).

The following aspects were analysed :

- Foundations: Assess the stability and integrity of the foundation structures.
- Floors: The floor conditions, including cracks, unevenness, and signs of wear examined.
- Wall Cracks: This subsection identifies and categorises wall cracks based on severity.
- Roofing: The roofs were inspected for leaks, sagging, and overall condition.
- Electricity: Checking electrical installations and safety measures.
- Plumbing: The evaluation of plumbing systems for leaks, blockages, and functionality.

The severity and extent of defects were evaluated, resulting in an average quality score rating between 45% and 60%. Lower scores were correlated with higher remediation costs. This study proposed an inspection and repair approach for optimal maintenance.

According to the scoring system, houses with more than 85% of their scores are good and pose little structural integrity risk. Houses between 50% and 85% require remedial works, ranging from minor to major structural repairs, and houses below 50% are unacceptable and need to be demolished.

4 DATA ANALYSIS

In KwaThema Township, three sections were identified as Deep Level, Riverside, and Masimini for the assessment of the housing conditions and ranked based on the critical repair needs of the classification of issues.

4.1 *Quality score rating analysis*

- assessment of housing conditions, in KwaThema
- Classification of issues (e.g., structural, electrical, plumbing)
- Identification of critical repair needs

According to Figure 2, the conditional assessment of low-cost housing in KwaThema Township was done focusing on three areas (Deep Level, Riverside, and Masimini). The assessment was classified as foundations, floors, structural walls, roofs, electrical, and plumbing. Issues were ranked based on their severity. A critical repair strategy was identified using a conditional index.

KWATHEMA TOWNSHIP					
	Deep Level	Riverside	Masimini	Avg	Ranking
FOUNDATION	1.0	2.1	3.0	2	4
SURFACE BED / SLAB - FLOOR	1.2	2.6	2.8	2	3
WALLS (EXT& INT.)	1.6	1.2	2.5	2	5
ROOFS	1.2	2.5	3.0	2	2
ELECTRICAL	2.5	3.0	3.0	3	1
Conditional Index	50.9	50.7	60.5		

Figure 2. KwaThema summary condition assessment rating.

The formula for the Conditional Index was also used: (Qureshi and Solanki 2019)

$$\boldsymbol{CIj = 100 - \left(\sum_{i=1}^{d} Wi.Si\right)/100}$$

where CI_J = Condition Index for the jth (component or section) (1)

W_i = Weight for deficiency (i);

S_i = Severity extent of deficiency (i);

5 RESULTS AND DISCUSSION

The study found that most low-cost houses exhibited moderate to severe defects. Common issues included foundation cracks, floor cracks, wall cracks(internal and external), roof leaks, and inadequate electrical wiring. Based on the ranking scale in Figure 2 and the conditional index in Figure 3, most houses in Deep level walls were cracked and buckled in certain areas and had to be demolished. The proposed repair strategy emphasizes cost-effective solutions, prioritising critical repairs while considering homeowners' financial constraints. By addressing these issues, the overall quality of low-cost housing can be improved.

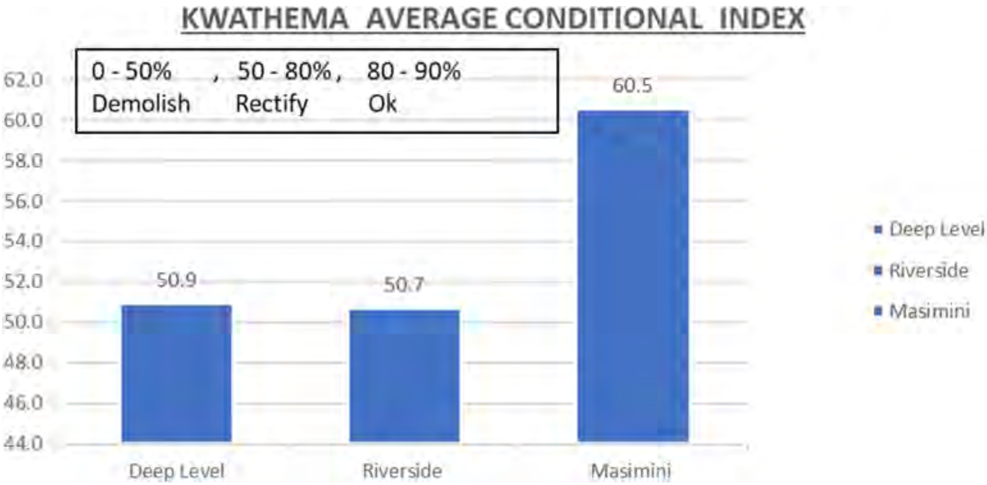

Figure 3. Average conditional index -KwaThema.

Implementing both proactive and reactive repairs effectively prevents homes from deteriorating into costly conditions. It is crucial to address house defects by prioritizing the most destructive ones. Immediate attention should be given to distress, dampness, or leakage. A repair plan based on the existing condition of houses ensures cost-sustainable maintenance, leading to enhancements in low-cost housing and its communities(Akinwande *et al.* 2024).

While this study has primarily focused on analyzing repair strategies for low-cost housing, it is essential to consider the context of settlements. Many houses exhibit defects across building components with variations in the type and extent of defects, even among similar housing layouts. The condition of a house is not influenced by its design and construction but by factors, like occupancy, location, and surroundings. All these factors should be taken into account when developing repair strategies.

5.1 *Correlation between quality score and remediation costs*

The research discovered a relationship between the Quality Score and the Remediation Cost on both the individual low-cost housing element level and for the entire building in the initial dataset. In the dataset, there was a stronger positive correlation for elements like overall structure, roof, walls, and the whole building with foundations being the only exception. This finding is crucial for creating a cost estimation model for repairing low-cost housing without any renovations.

The developed repair and maintenance cost model enhances the assessment of building conditions by identifying deficiencies and estimating remediation costs. It can be easily applied on-site while considering property attributes. Property owners can use this model to plan their budget for work and assess the associated expenses before a contractor works on the project. Additionally, cost consultants can leverage this approach to project remediation costs while property investors can evaluate the implications of investing in housing.

Maintenance Model

%	Physical Condition	Action Matrix
45-50 %	High Risk (Cost Factor : 1.5)	Significant remediation needs, Potential for major issues
51- 55 %	Medium Risk (Cost Factor: 1.2)	Moderate remediation required, proactive maintenance crucial
56 - 60%	Low Risk (Cost Factor : 1.0)	Minor repairs, routine maintenance sufficient

Figure 4. Correlation between scoring ratings and remedial cost.

5.2 *Limitations and constraints*

The following limitations are acknowledged:

- Data Scope: Our analysis focused solely on visual conditions and did not consider non-visual data or resident feedback.
- Generalisability: Although our findings apply to KwaThema Township, further research is needed to verify their generalisability.

6 CONCLUSION AND FUTURE RESEARCH DIRECTIONS

A visual assessment based on the condition inside and outside of the houses, and yard space, was developed. Data on socioeconomic factors and physical conditions of low-cost dwellings along with, their yards were also collected.

The absence of a culture of upkeep results in deterioration that necessitates financial assistance, for renovations. 65% to 77% of houses can still be fixed at the expense of the homeowners themselves. A step-by-step repair approach has also has been suggested. This repair plan can be adapted based on the state of the building components. Guidelines for replacing elements that are in a state of decay have been established. However, certain limitations are present, such as the analysis being restricted to conditions and not considering feedback from residents or nonvisual data.

6.1 *Summary of findings*

This paper sets out to determine a repair strategy for low-cost housing that would be effective in planning an incremental building process to gradually transform low-cost houses into more valuable assets. The analysis of the study encourages the following summary of the findings:

Overcrowding in low-cost housing was found to be a significant problem. Affordable homeowners lack space due to financial limitations and housing policies. It was proposed that the Informal Settlement Policy facilitates on-site upgrading for homeowners to gradually improve their buildings and add value to their properties. One of the proposed repair strategies is to consolidate the existing structure and add a second floor or loft as an for additional space. Extending the dwelling to the rear or front of the house can also help alleviate overcrowding and increase property value.

The repair strategy should allow for numerous changes with limited resources. The building envelope should support additional loads, and the structure should be strengthened before adding new rooms or building a second floor. The strategy should be adaptable and should be considered more as a design approach than a fixed solution. Engaging the homeowner is crucial for ensuring their needs are met in the final design.

6.2 *Recommendations for future research*

This study focused on types of repairs performed by low-income homeowners to improve housing conditions. Other possible repairs, whether identified or unidentified, should be documented to fully understand housing conditions. Each repair could be further analysed in terms of its associations with house conditions, including workmanship and material quality. These associations could help accurately assess housing value in the area.

It is recommended to conduct further research on low-cost housing developments to verify the generalisability of the results. Comparing housing condition valuations using the sales comparison approach after documented repairs may provide better insight into the value of repairs add value. Repairs should be recognised as necessary and typical by average homeowners in the area. Policymakers and housing developers should prioritise targeted investments in areas with lower condition indices. This could involve community-led rehabilitation projects, capacity building for homeowners, and partnerships with local organizations.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Experimental investigation of the impact of hail damage on roofing materials in low-income housing

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ABSTRACT: Damage from hail impacts is greater globally and poses a significant risk to the roofing materials. This paper presents the artificial hail impacts on the IBR 686 metal sheets with various thicknesses and grades. The objectives were to investigate the damage made to the roof sheets by artificial hailstones and to determine the performance and thickness of IBR sheet profiles while meeting stiffness criterion. The experimental lab test was conducted using the dynamic pneumatic gun to launch artificial hailstones of varying diameters onto samples of roof sheets of various thicknesses and grades. The numerical experiments were also conducted using Finite Element Model through Abaqus Explicit Software. There is an inverse relationship between the yield strength and dent depth brought on by ice ball impact. Moreover, it was found that the G300 IBR sheet which has a 0.46mm thickness, is the most susceptible to hail impact.

Keywords: Artificial hailstones, Dynamic pneumatic gun, IBR 686 metal sheets, Numerical experiment, Optimal IBR sheet profile

1 INTRODUCTION

Hail impact causes more damage globally. It has been reported that hail causes damage in South Africa with the cost estimated at ten million Rands annually (Le Roux and Olivier 1996). South Africa adopted the current standards of determining the impact of hailstorms and testing the performance of the roof sheets, however, the simulation in those standards cannot represent natural hailstones very well and a better understanding of hailstorm impacts on the built environment. The impact of hail on the roof sheets is a concern to domestic buildings and warehouses owners. As climate change worsens, hailstorms are anticipated to become more common and have a larger potential to cause property damage and injuries (Leslie *et.al* 2008 and Mahachi 2021). World Health Organization (2014) stated that the roof is a very important component of housing to be regarded as satisfactory for health occupancy.

There is vast evidence indicating that hailstone impacts cause extreme damage to the roof due to perforation and water ingress. In South Africa, there are challenges of hailstorms against the low-income housing roof sheets that are due to the low-cost cost material used when executing the roof structure. The South African building codes do not include any requirements for building cladding materials that can withstand hailstorms. The most used standards for testing the performance of roofing material against hail are Underwriters laboratories (UL) 2218 and FM 4473. Olivier (1996) mentioned that it is very important to

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indicate those regions experiencing high hail incidences. It is believed that roofing material gets easily damaged which could lead to more economic losses. According to Bell (2011), most damaged roof sheets are directly subjected to hail impact. Sharafi *et al.* (2013) and Mahachi *et al.* (2018), stated that steel roof sheets are most popular and used in domestic buildings in South Africa due to their less strength to weight, ease to assemble, longer life span due to coating, low maintenance cost, recyclability of material and availability, and wide range of cross-sectional shape and sizes.

The better performance and parameters of sheeting as roof resistance are controlled by the thickness, support conditions, and durability (Mlasi 2016). Generally, it is believed that the flatter the roofing system the more vulnerable it becomes. Similarly, Noon (2000), stated that the effect of hail on a roof cause more damage when imparting or striking at an angle of 90 degrees. Each year hailstorm causes substantial damage to buildings with very slow slope roof systems, therefore, this shows that the slope of the roof together with the angle of impact plays an important role in the resistance of the material.

According to Global Roofing Solution (GRS) (2021), the IBR 686 sheets are mostly used in South Africa, especially in low-income housing. The IBR sheet profiles, the parameters are investigated and established for several reasons, however, there is insufficient knowledge in the current works of literature on the relationship between the thickness and durability (stability) of the IBR sheets (SANS 10162-1, 2011; Eurocode 3- Part 1-3, 2006). UL 2218 (Underwriters Laboratories 1996) and FM 4473 (ANSI 2011) are standards that utilize steel balls and ice balls on the parts of the building to simulate hailstone impact, respectively. Nevertheless, the simulation in UL 2218 standard cannot represent natural hailstones very well. Furthermore, the most adopted standard used in South Africa to test impact resistance is ISO 6272-1:2011, which does not represent the natural hailstone as it utilizes a vertical guide tube. Bengtsson *et al*, (2007) stated that an increase in the thickness of the roofing material prohibits the chances of roof material yielding.

The work proposes the optimum grade and thickness of steel roofing sheets for low-income housing in terms of cost and performance and also, integrates the strength of the roofing material so that it may not show signs of yielding such as a fracture.

2 METHODOLOGY

2.1 *Research methodology overview*

In this research design, the quantitative approach is adopted, because this paper involves the collection and analysis of numerical data to identify the relationship between thickness and strength. It is usually known as a positivist study and deductive in nature. This approach outlines two methods that were utilized as follows respectively. The first method was conducted on the field where artificial hailstone (ice balls) were propelled at various velocities from 2 m distances to strike onto various specimens of roof sheet grades of various thicknesses to determine the performance and resistance of roofing material. The second method was Finite Element Method (FEM) as implemented in a computer simulation using software called Abaqus/CAE Explicit. By establishing the ideal quality and thickness of steel roofing sheets for low-income housing in terms of performance, the study intends to evaluate the steel sheets resistance to the impact of hailstones. Therefore, the outcomes of the fieldwork experiment are compared against the results of the computer simulation for validation.

2.2 *Research approach and design*

The experimental investigation was conducted to test the performance of various roof grades and various thicknesses.

2.2.1 *Dynamic hail impact test equipment (fieldwork)*

The test plan for the investigation makes use of the pneumatic propulsion of artificial hailstones. On a sample roof sheet, artificial hailstones of varying thicknesses and energies were launched. A laser that measures the speed of the ice balls and recording equipment made up of the hail gun. The experiment was carried out parallel to the ground because a hail gun that is mounted parallel to the ground was successfully utilized by most researchers, as given in Figure 1a. Ice balls with diameters of 18.5, 35.2, and 43.3, mm were propelled using the pneumatic gun (hail gun). In this study, artificial hailstones are spherical, pure ice balls of varying diameters that were cast in three different aluminium moulds, see Figure 1b. Since pure ice can be similar to the densities of natural hailstones, ice balls were chosen as artificial hailstones (Figure 1d). The freezer remained at minus 10°C in every instance and the ice balls were kept at a controlled temperature and placed in a cooler box with dry ice (solid carbon dioxide) to maintain the temperature, there was no mass loss during this investigation due to melting. Moreover, there was no mass loss while placing the ice ball in the hail gun from the cooler box. While the experiment was carried out in the summer, the test area's temperature was kept at room temperature between 26 and 28 degrees Celsius. Before the ice balls were launched onto the metal sheets, their mass in grams was measured; Figure 1c displays the mass scale.

(a) Experiment set-up

(b) The sizes of ice ball moulds

(c) An image indicating the mass of a 35.2 mm diameter artificial hailstone in grams

(d) Artificial hailstone made with pure tap water

Figure 1. Dynamic hail impact test equipment (Fieldwork).

Two sheet steel grades (G550 and G300) and two thicknesses (0.46 mm and 0.54 mm) were utilized as the test materials to examine the performance of the IBR sheets and the effects of dents caused by the impact of the ice balls. The IBR sheets are galvanized with Z275 and a total coated thickness of 0.54 mm and 0.46 mm for all tested IBR sheets. Figure 2 shows how the steel sheeting is fastened to aluminium purlins that are 600 mm/

Figure 2. Showing the purlins spacing on the roof truss.

60 cm apart from one another. Moreover, there were two scenarios involved, the first scenario is that the roof slope of 1:3 was initially used which improved the resistance of the roof sheets against the propelled artificial hailstone. This is because most of the ice balls bounced off on the roof sheet without causing any damage, however, the second scenario was fully adopted where the performance of the roof sheet was tested perpendicular (90-degree angle) to the hail gun because that is where the dents were visible.

The projectile was pointed perpendicularly at the gap in the middle of the two battens. According to SANS 10400 part L, the maximum spacing achieved in practice for purlins is 1200 mm. Furthermore, it was observed that the dent decreased with increasing spacing as more energy was lost to elastic vibration (damping). Kim *et al.* (2003) found that even while the boundary condition impacts stiffness, it does not significantly alter dynamic dent resistance. However, boundary conditions play a pivotal role in the workability of the roof structure. According to Juntikka and Olsson (2009), because a dynamic impact is localized, the force produced by the impact is independent of the boundary conditions.

The hail launcher was composed of a hail holder, a pneumatic gun mount, a barrel, a regulator, 100 litre air compressors, and a gas valve. The projectile was propelled by a compressor, which produced the required pneumatic pressure of 4 kPa. The barrel was equipped with a hollow, smooth-bore steel cylinder that was large enough to accommodate various-sized projectiles. The projectile was launched by pulling a trigger on a gas valve. The hail gun was fixed to the mount on the table, allowing for simple movement without disassembly and the hail gun was placed 2 m away from the specimen. The device recorded the velocity from the barrel in feet per second (fps) and therefore the velocity had to be converted to meters per second by dividing fps by a value of 3.281.

2.2.2 *Method of making artificial hail*

Given that ice balls are also composed of water, it is believed that their results will more accurately resemble natural hailstones (Crenshaw and Koontz 2001). The use of artificial hailstones to conduct the hail impact on the IBR sheets presents the worst-case scenario because, according to Changnon (1996), natural hailstones are slightly less dense than artificial hailstones because they are composed of alternating layers of clear and rime ice as well as air cavities. Since pure ice can be similar to the densities of natural hailstones, in this paper, the pure ice balls are chosen as artificial hailstones. Although ice makes up the majority of natural hailstones and since ice balls are simpler to create in any laboratory, ice is still seen to be the best substance to replicate hailstone. It is challenging for most researchers to replicate the chemical and mechanical properties of hailstones (Greenfeld 1969; Kim *et al.* 2003; Luong 2014; Swift 2013; Tippmann 2011). However, in this paper, the water from the tap was utilized to make the ice balls under minus 10°C temperature, and aluminium moulds of various sizes were used, as shown in Figure 1b. At prone regions, the density of hail increases approximately to 900 kg/m³ (Koontz 1991), hence the pure ice balls utilized in this work/study.

2.2.3 *Steel samples (IBR sheets) properties*

Due to local availability, only a limited number of steel samples were selected for the investigation to provide a diversity of target panels. This study utilized two grades of IBR sheets which are G550 and G300, furthermore, the sheet samples were tested using the pull-out tests in the laboratory, and the outcome data for the yield strengths of 300 MPa and 550 MPa, respectively, were accurate. Each grade had various thicknesses of 0.46 mm and 0.54 mm. Table 1 indicates the IBR sheets sample used in this research and are categorized as a class of commercial use.

Table 1. Showing sheet samples.

Steel grade	Thickness (mm)
G300	0.46
G300	0.54
G550	0.46
G550	0.54

2.3 *Abaqus/CAE explicit overview (finite element method based on computer simulation)*

Abaqus/CAE Explicit is a computational software developed by *Dassault Systemes Simulia Corp*. It is a powerful finite element analysis (FEA) tool designed to simulate the dynamic and extremely nonlinear behavior of structures under loading. This approach is suitable for simulations with short durations, large deformations, and contact interactions. It allows for the modeling of various structural and component types because it supports a broad variety of element types, including solid, shell, and wire.

2.3.1 *Finite element model in Abaqus/CAE explicit*

A flow diagram of the rationale employed to generate the model in Abaqus/CAE Explicit is shown in Figure 3.

2.3.2 *Abaqus/CAE explicit experimental setup*

The two materials that formed the model in this experimental setup were the artificial hailstones with various thicknesses and 686 IBR metal sheets of various thicknesses and grades. The IBR sheet with a fixed cover width of 686 mm. Two grades of IBR sheets which are G550 and G330 were modelled, furthermore, the data for the yield strengths used in the model properties were 550 MPa and 300 MPa, respectively. The sizes of the simulated artificial hailstones ranged from 18.5 to 43.3 mm in diameter, and the artificial hailstones were all spherical implying good results. The distance between the artificial hailstone and the roof sheet was kept constant throughout the simulation at a distance of 2 m, see Figure 4. In this paper, only the artificial hailstone impact on the IBR sheet was considered because it is the most important distinguishing factor for this research. For accurate results, the adopted meshing for the metal sheet was 0.01 and for the artificial hailstone was 0.002.

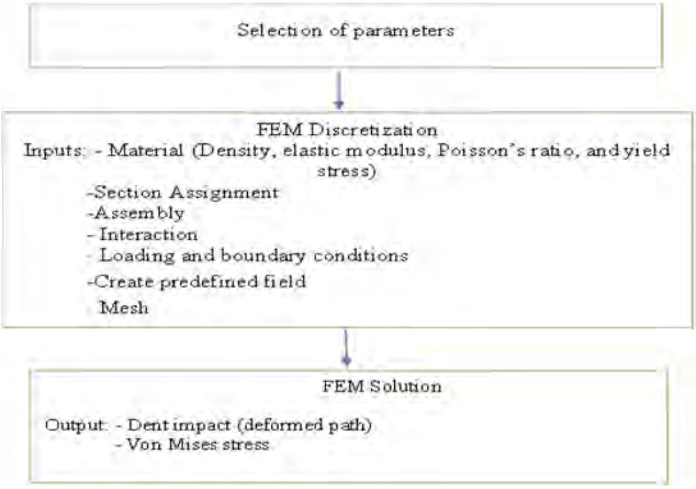

Figure 3. Diagram showing the progression of the Abaqus/CAE model used.

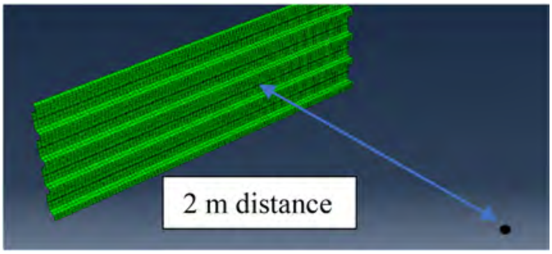

Figure 4. A model image showing a simulation of artificial hailstone and IBR sheet.

2.3.2.1 *Material and properties of IBR sheet* The material was demonstrated to have tri-linear elastic-plastic behaviour based on its elastic modulus (E) of 200 x 10^3 N/mm^2 and Poisson ratio (v) of 0.3. The adopted simplified stress-strain relationship for materials with Von Mises (Liu 2005) plasticity and linear elasticity is shown in Figure 5. Homogeneous shell sections have been utilized for the roof sheet in compliance with Simpson's integration rule.

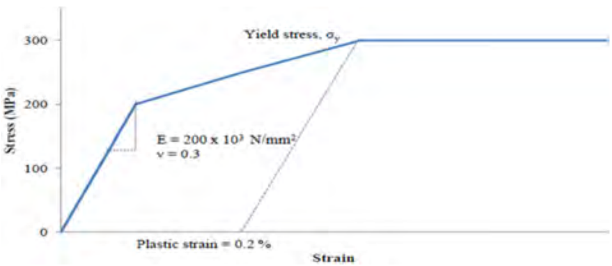

Figure 5. Simplified stress-strain relationship for steel (Case and Chilver 1964; Case *et al.* 1999)

2.3.2.2 *Global coordination system and boundary conditions in Abaqus/CAE explicit* X: is defined along the direction of impact (U1); Y is defined along the fixed edges of the sheet (U2); Z: is defined along the long free side of the sheet (U3) as illustrated in Figure 6.

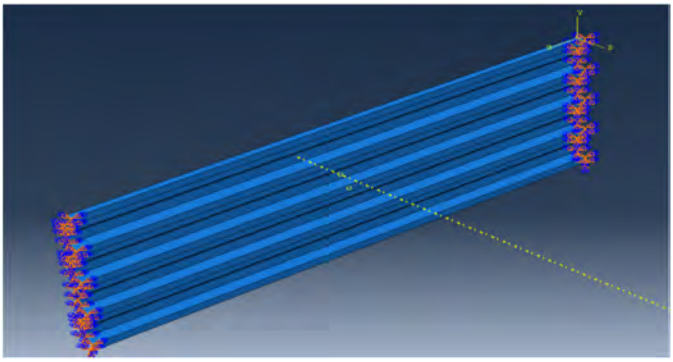

Figure 6. Showing the coordination system of boundary conditions.

2.3.2.3 *Modelling the load in Abaqus/CAE explicit* An initial step is automatically created by Abaqus/Explicit in which the boundary conditions are specified. Then, as illustrated in Figure 7, the loading step is made, applying the ice-ball impact load (P) to the sheet's upper surfaces. In this study, a conservative assumption is made by modelling the hailstorm as deformable because, in the laboratory experimental work, most ice balls after the impact shuttered, hence the deformable bodies of ice balls were adopted. The procedure type that was used is dynamic explicit with the effect of gravitational force.

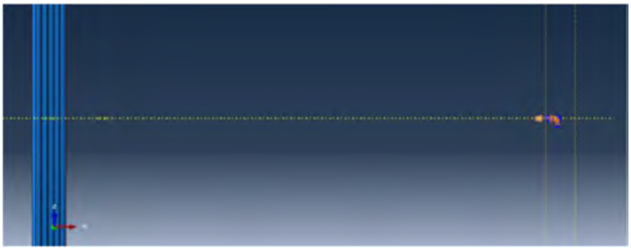

Figure 7. A model image showing the applied load and direction of the ice ball.

3 RESULTS AND DISCUSSIONS

This paper presents the results of IBR sheets of various thicknesses and strengths imparted by artificial hailstones (ice balls). Additionally, it includes a comparison between dent sizes determined by computer simulation (Abaqus/CAE Explicit) and those observed in the laboratory. It examines the dent depths and the effect of the ice ball and steel sheet thickness.

3.1 *Dynamic hail impact test outputs (fieldwork study)*

Table 2. Experiment results.

Sheet Grade	Thickness (mm)	Ice-balls Diameters (mm)			Projectile distance (m)	Velocity (m/s)	Impact energy(J)	Projectile integrity	Damage Remarks
		18.5	35.2	43.3					
G300	0.46				2	77.145	8.034	intact	Indentation
	0.46				2	26.35	7.29	shuttered	No indentation
	0.46				2	17.352	5.9	shuttered	Indentation
	0.54				2	60.777	4.987	intact	Indentation
G550	0.46				2	47.823	3.088	shuttered	No indentation
	0.54				2	17.179	3.098	shuttered	No indentation
	0.54				2	26.091	7.604	shuttered	No indentation
	0.46				2	54.254	3.974	intact	Slightly indentation
	0.46				2	15.051	2.37	Crack & shutters	No indentation
	0.46				2	14.347	2.161	intact	Indentation
	0.46				2	13.716	3.687	shuttered	Indentation

Source: Sekhukhune (2024)

3.2 *Abaqus/CAE explicit finite element model*

Table 3. Finite element model results.

ID	Sheet Grade	Thickness (mm)	Ice-balls Diameters (mm)			Velocity (m/s)	Maximum plastic Strain ($PE\times10^{-3}$)	Maximum Von Mises (stresses) ($S\times10^{8}$)	Dents (m)
			18.5	35.2	43.3				
1	G300	0.46				77.145	4.93	3.009	0.00045
2		0.46				26.35	3693	3.500	0.08
3		0.46				17.352	675.1	3.500	0.005
4		0.54				60.777	5.181	3.010	0.00054
5	G550	0.46				47.823	1.796	5.503	0.0008
6		0.54				17.179	1382	6.000	0.025
7		0.54				26.091	1100	6.000	0.008
8		0.46				54.254	1.279	5.502	0.0006
9		0.46				15.051	579.4	6.000	0.0125
10		0.46				13.716	200.3	5.879	0.0075

Source: Sekhukhune (2024)

The impact results from the lab and computer simulation varied by a slight margin because some of the ice balls had cracks and some trapped air inside of them. The ice balls remained intact in the finite element model, but many of them have shuttered in the lab experiment, which accounts for the slight variation in dent depth. In most recent hail impact research, ice balls were commonly used as artificial hailstones (Luong 2014; Sun *et al.* 2015). The finite element model utilized the same velocities that were measured during the experimental work in the lab. For G300 and G550 steel, the dent depth reduced as the yield stress of the steel sheet increased.

During the experimental work in the lab, most of the ice balls were shuttered after the impact, hence less kinetic energy was transferred to the steel sheet because kinetic energy is retained in the fractures of the ice balls that were broken during impact which resulted in a higher proportion of energy being transferred to the sound energy.

The results of the finite element model, shown in Table 3, show that the dent sizes decrease as the yield strength of the roof material and the thickness of the roof sheet increase. They also show that the relationship between the yield strength and dent depth caused by ice ball impact is inverse. The adopted roof slope was 1:3 which improved the resistance of the roof sheets against the propelled artificial hailstone because most of the ice balls bounced off on the roof sheet without causing any damage. On the other hand, Sharafi *et al.* (2013), recommended a slope of 6:12 using the theoretical based computer simulation. Kinetic energy is directly proportional to the stresses caused by the ice ball impact, therefore the dent sizes on the roof sheet are dependent on the kinetic energy produced by the simulated or propelled ice balls. Laurie (1960) conducted a similar experiment of different diameters of hailstone and indicated that the terminal velocity of hailstone is directly proportional to the size of the hailstone and the impact energy (kinetic energy).

Table 2 shows that the metal roof sheets are vulnerable to aesthetic damage since hail causes permanent indentations, which ultimately water will remain in the permanent dents and cause the metal roof to corrode and lead to water ingress. Furthermore, the results from the lab indicate that there was no sign of fracture or crack except for the dents. It is found that the G300 IBR sheet, which has a thickness of 0.46 mm, is the most vulnerable to hail impact, see Figures 8 & 9.

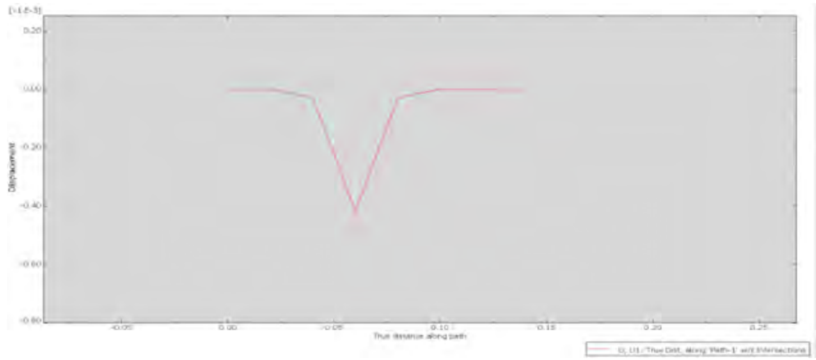

Figure 8. Shows the dent impact made by an 18.5mm ice ball on a G300 roof sheet of 0.46mm in thickness (Sekhukhune 2024).

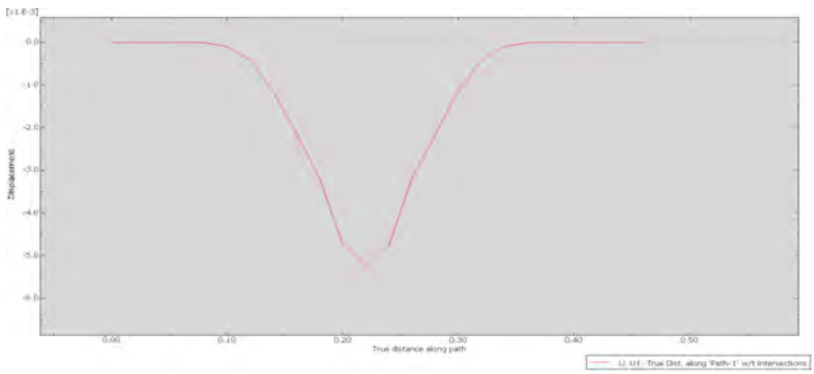

Figure 9. Shows the dent impact made by a 43.3mm ice ball on a G300 roof sheet of 0.46mm in thickness (Sekhukhune 2024).

4 CONCLUSION

Overall, the findings in this paper can lead to the development of improved building codes, standards for construction, and more resilient, cost-effective, and environmentally friendly roofing solutions for buildings in regions prone to hailstorms. Insurance firms can utilize the data produced by the simulations to evaluate risk variables and set more precise premium rates for properties located in areas that are prone to hailstorms.

The impact results from the lab and computer simulation varied by a slight margin because some of the ice balls had cracks and some trapped air inside of them. The finite element model uses the same velocities that were measured during the experimental work. Furthermore, the results from the experimental work indicate that there was no sign of fracture or crack except for the dents. In conclusion, it is found that the G300 IBR sheet, with 0.46 mm thickness, is the most vulnerable under the impact of artificial hailstone greater than 35.2mm in diameter at the speed of 26.35m/s. Lastly, the significance of this paper is that the residential areas that are situated in adverse regions where hailstorms occur frequently are covered in terms of which type of roof sheet materials are suitable to be used.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Use of Expanded Polystyrene Thermocol (EPT) in concrete: Sustainable solution for low-cost housing in South Africa

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ABSTRACT: This paper explored the use of Expanded Polystyrene Thermocol (EPT) beads in construction of low-housing projects. The mechanical and physical properties, including workability, density, compressive and flexural strengths, heat conductivity and drying shrinkage were assessed at varying percentages of EPT used to replace coarse aggregate of a 35 MPa control concrete mix. The discussion pivoted around the technical feasibility of EPT concrete when applied to the various components of required to construct a low-cost house in South Africa. The addition of EPT beads to concrete is found to negatively influence strength and drying shrinkage while enhances the workability, density, and thermal properties. EPT concrete produced by incorporating approximately 25% EPT beads by volume replacement of coarse aggregates is found suitable for low-cost houses applications.

Keywords: Expanded Polystyrene, Lightweight concrete, Compressive strength, Flexural strength, Low-cost Housing

1 INTRODUCTION

The issue of housing affordability has been pressing a significant portion of the population who struggles access adequate shelter. The demand for sustainable low-cost housing solutions in South Africa has intensified over the years due to rapid urbanization, population growth, and socioeconomic disparities as per Centre for Affordable Housing Finance [2023]. Addressing this need is paramount not only for ensuring basic human rights but also for fostering social and economic development. In response to this challenge, various materials and construction techniques have been explored for constructing affordable housing units. Among these, Expanded Polystyrene Thermocol concrete (EPT) has emerged as a sustainable promising option. This lightweight and versatile concrete material offers several advantages, including cost-effectiveness, thermal insulation properties, and environmental sustainability [Dhinakaran *et al.* 2017]. By using EPT concrete to achieve sustainable low-cost housing projects, not only can the affordability barrier be overcome, but also a significant contribution can be made towards waste management and environmental conservation.

This paper explores the use of Expanded Polystyrene Thermocol (EPT) beads in concrete for construction of sustainable low-cost housing projects. The objective is to evaluate the potential use of EPT-concrete for low-cost housing, examining its technical feasibility, advantages, and implications.

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2 LITERATURE REVIEW

The availability of housing for individuals earning less than R15 000 per month is severely restricted in South Africa, as noted in the Centre for Affordable Housing Finance of 2023. This scarcity is compounded by the limited ability of households in lower income brackets to secure private financing. Additionally, the strict criteria for subsidized housing set a baseline that limits the types of housing products the private sector is willing to provide, especially just above the subsidized level, according to Cross [2022]. In general, Port Elizabeth is the ideal city for those seeking low-cost housing, with an average property price of R1 100 000, as of 2019 [Hayworth and Melzer 2020]. It is further stated that Cape Town is the most expensive city, with an average property value of R5 755 317. According to CBN Homes [2021], 31.1 % of the affordable market is situated in Gauteng, 13% in the Western Cape and 12% in KwaZulu-Natal. The strive towards affordable infrastructure such as low-cost housing continues to be a subject of debate for some time in South Africa and in other countries within the African continent. Studies involving research that assess alternative low-cost construction materials have been highlighted on many occasions as a priority and are considered as a drive for sustainable development and a means of poverty alleviation.

Based on available research on the material, the use of EPT concrete in low-cost housing can provide a cost-effective and sustainable solution that can improve the living conditions of low-income households. The material's lightweight and insulating properties, makes it an attractive option for low-cost housing projects. EPT consists of lightweight cellular plastic beads, usually varying in diameter from 1 to 6 mm, and densities between 6 to 12 kg/m^3 [Omnexus 2021]. These beads are spherical and predominantly composed of approximately 98% air and 2% polystyrene [Omnexus 2021], produced from styrene and pentane. Primarily utilized in packaging and handling fragile items due to its shock-absorbing properties, EPT's low density makes it suitable for the creation of lightweight concrete by partially substituting the aggregate. This repurposing of EPT has garnered support from researchers such as [Kaptan *et al.* 2019], who noted its benefits in reducing self-weight and thermal conductivity in EPT concrete formulations.

Lightweight concrete, unlike conventional concrete, is characterized by its reduced weight. Various methods have been employed to manufacture it, one of which involves utilizing lightweight EPT balls as aggregate instead of the conventional crushed natural stones [Kole *et al.* 2017]. It's been suggested that EPT concrete is most suitable for structural elements, such as walls, cladding panels, footpaths, parapet walls, and composite flooring, where high compressive and tensile strength are not critical [Kole *et al.* 2017].

EPT concrete has been thoroughly researched in several critical areas. Studies have extensively examined its mechanical properties, including compressive, flexural, and tensile strengths, and its modulus of elasticity (Sadrmomtazi *et al.* 2012; Silva *et al.* 2014). The thermal properties of EPT concrete, such as thermal insulation and conductivity, have been well-documented, demonstrating its effectiveness in energy-efficient building materials (Demirboğa and Gül 2003). Additionally, durability aspects like freeze-thaw resistance and water absorption have been investigated to ensure performance in various environmental conditions (Gencel *et al.* 2011). Research has also delved into the acoustic properties of EPT concrete, particularly its sound insulation capabilities (Da Silva and Castro 2012). Environmental impact studies have focused on the sustainability of using recycled polystyrene, with lifecycle assessments highlighting its ecological benefits (Silva *et al.* 2014). Moreover, optimal mix proportions and the influence of various admixtures on the workability and performance of EPT concrete have been extensively studied (Nambiar and Ramamurthy 2006).

More studies are needed on how EPT concrete degrades over time, especially in different environmental conditions. While some studies exist on fire resistance of EPT concrete, more comprehensive research is needed including its structural integrity during and after exposure to high temperatures. Limited research exists on how EPT concrete interacts chemically with other construction materials, such as coatings, sealants, and reinforcements, and comprehensive cost-benefit analyses are needed to compare EPT concrete with traditional concrete in various applications, considering factors like material costs, labor, and lifecycle savings. Addressing these unexplored areas could further enhance the potential applications and benefits of EPT concrete in the construction industry.

3 METHODOLOGY

The information presented herein is derived from the author's Master of Engineering research work (Mashava 2024), which extensively analysed distinct sets of tests encompassing mechanical and physical properties. This master research work serves as the foundation for the insights and findings conveyed, offering a thorough exploration into various aspects of the subject matter. Through thorough experimentation and analysis, the author has endeavoured to provide a comprehensive understanding of the topic. In the experimental program, conventional concrete used as a reference mix is proportioned according to the South African mix design method (Fulton 2009) to have 35 MPa cube strength at 28 days and 75 mm slump, which is typical concrete used on low-cost housing and general-purpose applications. The mix is composed of cement used is CEM I 42.5 all-purpose cement, 22.4 mm maximum size granite coarse aggregates with relative density of 2.694, crusher sand with relative density of 2.689, plasticiser, and municipal water. Varying percentages of EPT balls are used to replace the same volume of coarse aggregate of the reference mix. The EPT beads of sizes ranging between 5 and 2 mm, with relative density of 0.023 were used. Concrete mixing was done in accordance with to SANS 5861-1: 2006. The EPT balls were added to the wet mix while mixer is rotating. Standard slump tests were conducted as soon as the mixing is completed in accordance with SANS5861: 2006.

Standard cube and beam specimens were manufactured and subjected to standard water curing. Standard cubes measuring 150 x 150 x 150 mm were used to test the compressive strength in accordance with SANS5863: 2006 and assess the heat conductivity factor as per SANS8301: 2010. Standard flexure beams measuring 750 x 150 x 150 mm tested according to SANS5864: 2006, and drying shrinkage beam size of 300 x 100 x 100 mm tested according to the SANS6085: 2006 methods.

4 RESULTS ANALYSIS

The average results are shown on Table 1 below. The results indicate that partial replacement of coarse aggregates by EPT beads improves concrete workability, improves thermal insulation, reduces density, reduces compressive and flexural strength, and marginally increases drying shrinkage. At 25% EPT, the workability increases by 22%, thermal

Table 1. Mechanical and physical results of concrete.

EPT volume replacement (%)	Workability (mm)	Density (Kg/m^3)	28 days compressive strength (MPa)	28 days Flexural strength (MPa)	Heat conductivity (W.m.k)	Drying shrinkage (%)
0	83	2364	38.63	5.53	0.31	0.019
5	83	2346	38.30	5.37	0.28	0.018
10	87	2335	38.12	4.62	0.28	0.019
15	93	2267	34.21	4.29	0.26	0.020
20	98	2222	25.00	3.78	0.25	0.020
25	101	2157	25.05	3.57	0.24	0.021
50	109	1920	15.43	2.22	0.21	0.022

conductivity improves by 23%, density reduces by 9%, compressive and flexural strengths reduce by 35%, and drying shrinkage increases by 10%. It's noticeable that an EPT percentage has a varying impact on the different properties. Therefore, the trade-off between the EPT percentage and a physical or mechanical property shall be considered for a particular application. The compressive strength result's trend pertains well to the findings by Tamut *et al.* (2014), where they had replacements of 5, 10, 15, 20, 25 and 30% and found the compressive strength to be 91, 77, 71, 63, 56 and 45% respectively as compared to the control concrete. However, it appears that EPT replacement larger than 25% has a significant impact on concrete compressive and flexural strength. As a result of EPT beads being hydrophobic, there exist no strong bond between them and the cement paste, which results in weak spots on concrete and thereby decreased strength.

The reduction in compressive strength may attribute to the bond characteristics in the paste-EPT beads interface. Concrete's thermal conductivity decreased along with an increase of EPT in concrete. This type of concrete is energy efficient as it would reduce the need for air conditioning for in areas with high and low temperature weather conditions. Cold storerooms can also be constructed from EPT concrete. A maximum increase of 13% is found for concrete with 50% EPT replacement. The drying shrinkage findings are in line with relevant literature such as the work by Maghfouri *et al.* (2022). In South Africa, the acceptable drying shrinkage limit for normal concrete is determined by the South African National Standard (SANS) 5861-2:2016. According to this standard, the acceptable drying shrinkage limit for normal weight concrete (NWC) is 0.006 % of the member length for restrained shrinkage and 0.10% for unrestrained shrinkage. The concrete on study falls on unrestrained shrinkage, as it is not supported by anything but just a block. From the results obtained, concrete from 0 to 50% replacement fall within the acceptable shrinkage limit of 0.10%.

5 DISCUSSION

5.1 *Workability*

Workability refers to how easily concrete can be mixed, poured, compacted, and finished (Fulton 2009). From Table 1 above, the workability of EPT concrete is within the range of the values prescribed for conventional concrete making the material suitable for use of simple construction equipment and labour-intensive techniques. This correlates well with the findings of the study by Thomas *et al.* (2020).

5.2 *Compressive and flexural strength properties*

Table 1 shows the compressive strength results of 5, 10, 15, 20, 25 and 50% EPT replacement indicate that at 28 days the compressive strength was found to be 99, 98, 89, 65, 55 and 40 % respectively, when compared to the normal concrete. The result's trend pertains well to the findings by Tamut *et al.* (2014), where they had replacements of 5, 10, 15, 20, 25 and 30% and found the compressive strength to be 91, 77, 71, 63, 56 and 45% respectively as compared to the control concrete. However, it appears that EPT replacement larger than 25% has a significant impact on concrete compressive strength. The flexural strength results of 0, 5, 10, 15, 20, 25 and 50 % replacement indicate that 7-day strength was reduced by 10, 25, 31, 41, 44 and 61%, respectively as compared to control mix while at 28 days, the flexural strength was reduced by 3, 16, 22, 32, 35 and 60%, respectively. Regardless of other design factors, it appears that EPT replacement of up to 25% result in flexural strength that is within the typical range of values used for floor slab applications. As a result of EPT beads being hydrophobic, there exist no strong bond between them and the cement paste, which results in weak spots on concrete and thereby decreased strength. The reduction in compressive strength may attribute to the bond characteristics in the paste-EPT beads interface.

Typical strip foundation requires concrete materials which are characterized by a cube compressive strength of about 25 MPa. Coarse aggregates replacement by EPT of up to 25 percent seems to provide an EPT concrete suitable for foundation applications. It is worth pointing out that the lower dead load applied on the foundation, because of the lighter mass/weight of other building components, can generate savings in terms of the strip foundation size and reinforcement requirements. However, due to the interaction of the foundation's concrete with soil chemical composition, the assessment of EPT concrete durability or foundation protections are crucial. The interaction between reinforcing steel and EPT concrete is a subject for additional research.

Considering the floor slab component of a typical masonry brick house, concrete with 25 percent EPT is revealed to have about 3.57 MPa flexural strength at 28 days, refer to Table 1, which is equivalent to typical conventional concrete usually prescribed for such applications. EPT concrete can be molded into wall panels, blocks, or bricks which can be used to construct the exterior and interior walls of the house. As per AfriSam bricks and blocks guide 2007, the masonry blocks or bricks is required to have minimum compressive strength range between 3.5 and 21 MPa, considering the other physical properties stated in the standard specification by SANS 1215. However, concrete can provide some liberty in terms of meeting the strength requirements for masonry block and bricks. This can be achieved by selecting the amount of EPT incorporation based on the strength requirement. The same applies to in-situ slabs, panels, or tiles that can be manufactured using EPT concrete to construct the roof of the low-cost house.

In the recent past, South Africa has had numerous fires breaking incidences, especially for settlements where there are shacks built using metal and wood materials [Police Department 2023]. It should be noted that EPT in the form of loose beads is flammable and therefore not a fireproof material. Therefore, the fire resistance of EPT concrete is considered to play a significant role in terms of the material acceptance for low-cost houses. In other words, strength properties may not be the only factor to consider but also the fire resistance of EPT concrete. Further investigation is required to qualify the inclusion of EPT in a concrete mix used for building construction as per the SANS 428 fire performance requirements.

5.3 *Thermal insulation properties*

The EPT concrete showed improved thermal insulation when compared to normal concrete, according to the results. Concrete's thermal conductivity capacity dropped from 0.31 W/m. K to 0.21 W/m. K when EPT content was added in increments of 0 to 50 %. Thermal conductivity decreases by 32% between 0 and 50% EPT replacement. This type of concrete is energy efficient as it would reduce the need for air conditioning for in areas with high and low temperature weather conditions. Cold storerooms can also be constructed from EPT concrete. The results obtained from this study are comparable to the results of (Wongkvanklom *et al.* 2021), where the concrete with density of 1200-1000 kg/m3 had the thermal conductivity of 0.35-0.26 W/m. K.

Energy preservation and air conditioning efficiency are becoming a requirement as part of the design standards for new buildings. Normally, a building which comprises of a floor, walls, and roof, controls heat gain in summer and heat loss in winter. Ideally, the building material is required to maximise the exclusion of heat in summer, and trap and store warmth in winter to increase the effectiveness of the building, creating much more comfortable and less expensive to maintain living environments. Such a structure is advantageous because it mitigates high electrical consumption due to air conditioning.

As per SANS 10400 XA, South Africa will be implementing laws with the goal to establish Energy Efficiency Standards for Buildings. To this end, South Africa's building code is expected to include sections that talks to energy efficiency requirements, and thermal insulation will be required in all new construction projects. The insulation capabilities of EPT concrete as inferred by the decrease of conductivity factor ranging from 0.03 to 0.04 W/m. K has the potential and can play a significant role and contribute to the adherence in terms of these requirements. Apart from EPT concrete heat insulation capabilities, the material can be used to manufacture hollow block that can provide additional control on heat exchange between the interior and the exterior of the house.

5.4 *Drying shrinkage*

The results indicate that the drying shrinkage increased as EPT content increased in concrete. A maximum increase of 13% is found for concrete with 50% EPT replacement. The drying shrinkage findings are in line with relevant literature such as the work by Maghfouri *et al.* (2022). The increase in drying shrinkage can be explained as the difference in elastic modulus on EPT beads and natural coarse aggregates. Concrete with natural aggregates that have higher elastic modulus and rougher surfaces when compared to EPT beads tend to be more resistant to shrinkage.

Concrete loses volume because of moisture evaporating from it after curing stops. If concrete is restrained, it leads to cracking. In relatively long and restrained structures, joints must be established to accommodate the movement brought on by drying shrinkage. In South Africa, the acceptable drying shrinkage limit for normal concrete is determined by the South African National Standard (SANS) 5861-2:2016. According to this standard, the acceptable drying shrinkage limit for normal weight concrete (NWC) is 0.006 % of the member length for restrained shrinkage and 0.10% for unrestrained shrinkage. The concrete on study falls on unrestrained shrinkage, as it is not supported by anything but just a block. From the results obtained, concrete from 0 to 50% replacement falls within the acceptable shrinkage limit of 0.10%. This indicates that shrinkage will not be a precluding factor in terms of low-cost houses construction.

5.5 *Evaluating EPT concrete for low-cost housing projects*

The engineering properties of EPT concrete show potential for low-cost housing applications. Among possible applications of EPT concrete in low-cost housing projects is strip foundation, floor slab, wall panels, concrete blocks, bricks, and roof panels. In general, the use of EPT concrete in low-cost housing is expected to provide a cost-effective and sustainable solution that can improve the living conditions of low-income households.

5.6 *Low-cost houses construction*

In the context of low-cost housing in South Africa, the construction of houses in a manner that is efficient in terms of cost and labour-intensive construction is encouraged by the government and other non-governmental organisations. The reduced labour intensity and construction time associated with EPT concrete can help expedite housing projects, meeting the demand for affordable housing within shorter timeframes. Labour-intensive construction approach is often employed in low-cost housing projects in South Africa. Concrete with low density, i.e., lighter in weight for the same volume as compared to conventional concrete, pertains well to this application as it generates savings in terms of manpower required for handling concrete mix. For example, once rural women are trained on it, they would be able to build these houses themselves, as the materials are mostly lightweight and manageable. Using EPT concrete for low-cost houses can reduce construction costs, however, (cost analysis needs to be done for every project. The material itself is perceived to be cost-effective, and its lightweight nature can potentially speed up construction since it can be handled by a smaller number of workers, leading to further cost savings. This is in addition to the savings in terms of materials cost.

It should be noted that a higher EPT content results in a lower compressive strength but lighter concrete and improved insulation properties. However, the balance should be carefully considered between these three properties when selecting the volume of EPT replacing the coarse aggregates in the reference mix.

An experiment of a full-scale house that was conducted for the Expanded Polystyrene Association of Southern Africa, EPSASA (2009). In the study, an example house was built using intact EPT in the form of panels as insulation for the floor slab and hollow EPT block filled with concrete. The walls were then plastered to cover the relatively weak EPT surface. This was built in 14 days, weather permitting by a trained team. The total cost of this project was not disclosed.

The Moladi system is a construction system that was founded in 1986 in South Africa. The objective of the system is to achieve rapid house construction by means of recyclable, re-usable and removable formwork moulds. Concrete/Mortar fills the formwork to form the wall structures of the house. The formwork panels can be re-used up to 50 times therefore making the system cost effective as it can be repeatedly applied (Moladi 2018). The Moladi construction system includes a raft foundation, superstructure, Moladi bonding agent, windows, doors, ceilings, and a roof (Moladi 2018) (Figures 5.1 to 5.3). A complete Moladi unit with 2 bedrooms, 1 bathroom with an open plan lounge and a kitchen costs R39,017.19 which took only one day to complete. A combination of this system and EPT concrete can bring a relieve to South Africa housing.

5.7 *Sustainability of EPT concrete houses*

The United Nations Development Goals (UN SDGs) are a set of 17 global goals adopted by all UN member states in 2015 as part of the 2030 Agenda for Sustainable Development. These goals aim to address various social, economic, and environmental challenges facing the world today. Concerning sustainability, the use of EPT as a component in concrete is meant to replace natural aggregates, use of waste material, and preserve energy when used for housing projects. Building of low-cost houses, is well in line with the United Nation's Sustainable Development goal no 9 - "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", goal no 11 - "Make cities and human settlements inclusive, safe, resilient and sustainable", and goal no 12 - "Ensure sustainable consumption and production patterns". Using recycled EPT in concrete reduces environmental impact and supports eco-friendly construction methods.

Also, EPT concrete offers benefits, its usage might need to be combined with other construction techniques or materials to ensure structural integrity and longevity. EPT is a recyclable material, which aligns with the growing emphasis on sustainable building practices. The production of EPT concrete typically generates fewer greenhouse gases compared to traditional concrete production, contributing to a lower carbon footprint. Additionally. By incorporating locally accessible waste materials such as EPT, the adverse environmental effects of the infrastructure being constructed in an area can mitigated. The ability of sustainable building materials and structures to withstand natural disasters and climate fluctuation can be used to assess their suitability. In every circumstance, there is a need for technological advancements and information sharing with local populations. To produce more sustainable building materials, locals can be made aware of these resources and possibly educated on how to build their own affordable homes, that way, they could use EPT to replace typical materials used to build metal-wood shacks. It is worth pointing out that the appropriate technology to use must not ignore factors such as location, climate, local requirements, available resources, and cultural considerations. Future study must be conducted in this regard.

6 CONCLUSION

In conclusion, incorporating expanded polystyrene thermocol (EPT) in concrete brings favourable change in terms of workability, density and heat conductivity while reduces strength and slightly increases drying shrinkage. However, EPT dosage requires careful optimization for a particular application. Coarse aggregates in conventional normal strength concrete can be replaced by 25% of EPT balls by volume and the EPT concrete can be used for structural applications.

Adoption of the use of Expanded Polystyrene Thermocol (EPT) in concrete for low-cost housing in South Africa can significantly reduce construction costs and improve thermal and sound insulation in south Africa's houses. It can promote sustainability by recycling waste materials and lowering the carbon footprint. This approach can provide affordable housing, accelerate construction processes, and create job opportunities, enhancing local economies and living conditions. Moreover, it aligns with sustainable development goals, fostering social equity and addressing housing shortages effectively.

Future research is required to study the fire resistance properties and durability properties of EPT concrete. Additionally cost analysis will be required to assess the economic feasibility of EPT concrete houses as compared to existing alternatives.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Potential use of Zambian clay and laterite as soil liner in tailings dam construction

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ABSTRACT: Tailings are discharged directly into rivers, valleys, and surrounding due to the absence of tailing containments at artisanal and small-scale mining sites leading to environmental pollution. Synthetic liners are expensive, however, compacted natural soil has been found to be more cost-effective. This study aimed to undertake a laboratory evaluation of natural clay and laterite from Zambia as a potential soil liner. The laterite soil sample was grouped into three depending on the range of particle size and was designated as LS_1, LS_2 and LS_3. Results from the test indicate that the hydraulic conductivity of LS_2 and LS_3 were in the order of 10^{-9}m/s, LS_1 was in the order of 10^{-8}m/s at hydraulic gradients of 11 and 15. At a hydraulic gradient of 17.6, the hydraulic conductivity of LS_2 and LS_3 increased to an order of 10^{-8}m/s. The hydraulic conductivity of the clay sample was within 10^{-10}m/s at the different hydraulic gradients.

Keywords: Mining, tailings, liner, clay, laterite

1 INTRODUCTION

Gold is the most mined mineral in Sub-Saharan Africa due to its abundance. It is mined on large-scale, medium-scale, small-scale and artisanal scale (UNEP 2013). Small scale gold mining sites are predominant in most rural communities across the sub-region (UNEP 2019). The contribution of artisanal and small-scale gold mining (ASGM) to the world's gold production stood at 20% as reported by IGF, (2017).

The abundance of gold in Zambia and the ease of extraction has resulted in several artisanal and small-scale gold mining operations across the country though statistics on the gold production is scanty. ASGM activities are predominant within the Mwembeshi Shear Zone. The Ministry of Mines and Minerals Development (MMMD) announced in 2016 the availability of high-grade gold in areas such as Vubwi, Kampoko and Rufunsa (GEUS 2018). This revelation is an indication of the likelihood of an increase in ASGM operations within these areas. Thousands of people depend on ASGM as a source of livelihood making it one of the most important sectors of the economy (Kambani 2002: ZEMA 2020). Notwithstanding the economic benefits of this industry, it has become a threat to environmental health due to bad mining practices such as poor tailings management. Tailings

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effluents may contain toxic chemicals such as mercury and cyanide utilized in the ore processing, high levels of acidity and turbidity and other leached heavy metals at high concentrations. Artisanal and small-scale gold mining is known to be the largest source of the world's mercury emissions, averaging 800 tons/year representing 37% (AMAP/UNEP 2013). The ratio of mercury to gold used in gold amalgamation in some ASGM sites in Zambia is reported to be 2:1. Larger proportion of this mercury ends up in the air, land and water bodies (ZEMA 2020).

In most cases, tailings from small scale mining operations in developing countries are discharged directly into drains, rivers and surrounding sites due to the non-availability of tailings containment systems leading to soil, surface and groundwater pollution (Amedjoe and Gawu 2013). High concentrations of heavy metals in water bodies have serious repercussions on aquatic life and are a threat to the food chain. A study by Mwilola *et al.* (2020) revealed that the concentration of lead, zinc and Cadmium present in maize grain grown in the Kabwe mining area is above the maximum threshold.

Lung, kidney, respiratory and skin diseases as well as neuro-developmental problems in foetus such as mental retardation, vision and hearing disorders, delayed development, speaking disorders and memory loss have been attributed to high concentrations of heavy metals within the body (Mwilola *et al.* 2020; Shamlaye *et al.* 2019; WHO/FAO 2010).

Proper implementation of tailings management at the ASGM site through the construction of containments is key in dealing with mining-related contaminants and their associated environmental impacts. The best available techniques that are efficient, readily available, and cost-effective to prevent and or reduce the release of mercury and other heavy metals into air, water and land must be adopted (UNEP 2019; ZEMA 2020). One aspect of dealing with the environmental menace of small-scale mining is proper tailings management (UNECA 2011; US EPA 2019). Most large scale mining operations are under strict supervision from regulatory authorities hence adherence to mining regulations. The use of synthetic liners in tailing dam construction in large scale mining operations is a common practice. This cannot be said in the case of artisanal and small scale mining operations. The absence of tailing containments or the presence of unlined ponds at the small scale mining sites may be due to the high cost of synthetic liners such as high-density polyethlyene geomembrane and geosynthetic clay liners which may increase their operational cost. The lack of technical knowhow on alternate methods of lining tailing containment by small scale mining operators has also resulted in the poor tailings management. The use of compacted natural soils, processed and chemically-modified clay have been found to be a preferred technique for lining impoundment due to its availability and economic reasons (Akayuli *et al.* 2013; Victoria Earth Resources Regulation 2017; US EPA 2019).

Among the factors that control the permeability of compacted clay liner are mineralogical and physiochemical properties, compaction density and moisture content, hydraulic gradient across the liner, particle composition and properties of the permeating fluid. Other properties such as chemical adsorption potential may also be considered. Rowe *et al.* (1995) indicated that clay soil requirement as a liner should have permeability not exceeding 10^{-9}m/s, compatible with permeant, and should be able to plug the pore space upon saturation. According to UK Environmental Agency, (2009), a natural liner should have a gravel content of not more than 30% and, fine content of not less than 20% of which the clay content should not be less than 8%. The plasticity index should be between 10% and 65% and hydraulic conductivity not exceeding 10^{-10}m/s.

Most studies on artisanal and small-scale mining focused on the socio-economic and environmental impact. Research into safe mining through the application of engineering principles in tailing management has not been given the needed attention. There have been little practical approach from the engineering point of view in dealing with tailings from ASGM. Natural clay and laterite are readily available in Zambia and may have the potential for use as soil liner but has not been adequately exploited. This study aimed to undertake a laboratory evaluation of natural clay and laterite from Zambia as a potential liner for tailings dam construction for artisanal and small-scale mining operations. This study will help to improve tailing containment infrastructure at the mine site leading to responsible mining hence protecting the environment from mining related contaminants.

2 MATERIALS AND METHODS

2.1 *Sample collection and preparation*

Laterite soil was sourced from Lusaka South (Shantumbu area) and the clayey soil was sourced from the Goma fields (UNZA). Laterite soil was excavated from a pit between 1m-1.50m while the clay soil was obtained from an excavation between 0.5m-1.0m. Samples were bagged and transported to the geotechnical engineering laboratory for drying. Samples were air dried for about a week, bagged in airtight sacks and kept for testing. The bulk clay soil was passed through 6.7mm sieve and is referred CL sample. Part of the bulk laterite soil was passed through 26.5mm BS sieve whilst other parts were passed through 13.2mm and 6.7mm BS sieves giving rise to three different laterite samples with different range of particle sizes as shown in Table 1.

Table 1. Groups of laterite soil samples.

Group	Range of particle size	Designation
1	Passing through 26.5mm sieve	LS_1
2	Passing through 13.2mm sieve	LS_2
3	Passing through 6.7mm sieve	LS_3

Source: Author (2024)

2.2 *Data collection and processing*

2.2.1 *Physical properties*

The Atterberg limit test was performed to determine the liquid limit, plastic limit and linear shrinkage. The Cone Penetrometer was used to perform the liquid limit test while the plastic limit was determined using the hand rolling method (BS 1377-2, 2022). The Specific gravity test was performed in accordance with British standard using the small pycnometer method for the fine sample and the gas jar for the coarse samples (BS 1377-2, 2022). The particle size distribution of the samples were determined in accordance with British standard using both wet sieving and sedimentation by hydrometer analysis (BS 1377-2, 2022). The physical properties tests helped to determine the effect of fine, clay and gravel contents as well as plasticity index on the permeability of the compacted soil. Compaction test was performed in accordance with the British standard that makes use of 2.5kg rammer falling freely through 305mm at 25 blows per layer for 3 layers (BS 1377-4, 2022). The free swell index was conducted in accordance with Indian method of test for soils measurement of free swell of soils using water and kerosene (IS 2720-40, 1977). The specimen for permeability test was compacted to a diameter of 99mm, 123mm high and at a density corresponding to 2% above the optimum moisture. Frempong and Yanful, (2006) indicated that sample compacted at the wet of optimum moisture has a reduced permeability than that compacted at the dry of optimum. Before readings were recorded, the samples were saturated for a period of three days and effluent were observed from the outflow valve of the permeameter. The hydraulic conductivity was determined at four different hydraulic gradients (11, 15, 17.6 and 32) using tap water as a permeant flowing trough 8mm diameter standpipe. The ASTM standard test method for measurement of hydraulic conductivity of saturated porous materials using a rigid wall permeameter with constant tail water elevation was used (ASTM D5856, 2015).

2.2.2 *Mineralogical properties*

The mineralogical composition of the soil samples were determined through X-ray diffraction (XRD). The air-dried samples passing through 100μm sieve were used. About 5mg–10mg of the ground sample was placed on an XRD holder and inserted in the XRD equipment for analysis. The equipment used was the Olympus TERRA-538 portable XRD analyzer. Mineral phases in the sample were determined by the X'PERT HIGHSCORE PLUS software. The use of the XRD for mineralogical determination helped to assess the effect of soil minerals on the permeability of compacted soil.

2.2.3 *Chemical and physio-chemical analysis on samples*

The hydrogen ions concentration in the soil was determined through ASTM D4972, Method A using digital pH meter with both distilled water and 0.01M $CaCl_2$ solution in a ratio of 1:1 (soil: distilled water or $CaCl_2$) (ASTM D4972, 2015). The electrical conductivity was determined in accordance with FAO Standard Operating Procedure for soil electrical conductivity, soil/water, 1:5 using digital electrical conductivity meter (FAO 2021). The Atomic Absorption Spectrophotometer (AAS) was used to determine elemental and heavy metal concentrations.

2.3 *Test plan*

The procedure taken to execute this study is presented in a flowchart shown in Figure 1.

Figure 1. Data collection procedure. Source: Author (2024).

3 RESULTS AND DISCUSSION

3.1 *Physical properties of soil samples*

The results from specific gravity test of the laterite indicated decreased specific gravity value with increase in particle size as shown in Table 2. This may be attributed to the bigger voids present in the larger particle size range. LS_1, LS_2 and LS_3 have same liquid limit and plasticity index and FSI because they were obtained from the same soil sample but different gradation as indicated in Table 1. Passing each sample through 0.425mm BS sieve yield same results. The particle composition and Atterberg limit properties of soil sample are key due to the high influence of fine and gravel contents and plasticity index on hydraulic conductivity. The plasticity index and the particle gradation of all the samples meet the requirement for use as a liner (UK Environmental Agency 2009). The particle size distribution curves for the

Table 2. Summary of physical properties of soil samples.

Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PI (%)	Gs	USC	MDD (g/cm^3)	OMC (%)	FSI (%)
LS_3	1	45	26	28			2.6	SC	1.90	15	
LS_2	11	50	23	16	33	17	2.5	SM	1.87	15	21
LS_1	30	37	21	12			2.4	SG	1.88	11.5	
CL	3	28	28	41	42	27	2.7	CL	1.76	19	26

Source: Author (2024).

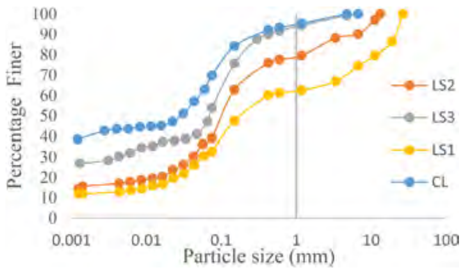

Figure 2. Particle size distribution curve for laterite samples. Source: Author (2024).

three particle size ranges of laterite soil and the clay sample used for this study are plotted as shown in Figure 2. Summary of the physical properties for the various soil samples have been presented in Table 2.

The maximum dry density (MDD) and the optimum moisture (OMC) content were clearly defined for all samples. Results from the compaction test indicate an increase in OMC with increase in fine content. This may be attributed to the larger specific surface area of the fine particles and hence be able to absorb significant amount of water into its lattice (Rowe *et al.* 1995). The decrease in OMC for LS_1 may be attributed to the high gravel (30%) and low clay (12%) contents. There was no significant change in MDD for all the three range of particle size for laterite. The MDD of the clay was lower than that of the laterite whilst the OMC was higher than the laterite. The large proportion of clay particles and clay mineral present in the CL sample may have contributed to this decrease in MDD and an increase in OMC. The findings from the dry density-water content characteristics of the samples used has been shown in and Figure 3.

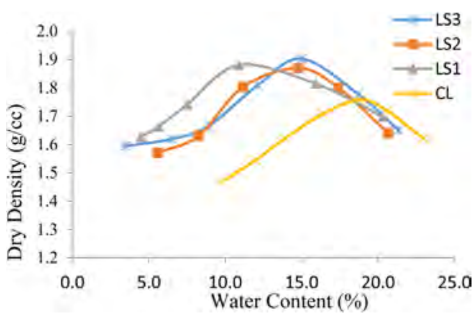

Figure 3. Compaction curve for the various samples. Source: Author (2024).

3.2 *Chemical properties of the soil samples*

The pH of the laterite soil obtained using distilled water was found to be 6.8 and 0.01M of $CaCl_2$ solution resulted in a pH of 6.4 whilst that of the clay sample tested with distilled water was found to be 6.9 and 6.7 in 0.01M of $CaCl_2$ solution. These values agree with ASTM D4972 as Calcium displaces exchangeable aluminium leading to less release of aluminium in the $Cacl_2$ solution hence lower pH. The pH values imply the soil samples are near neutral. The electrical conductivity of the laterite sample was found to be 211μS/cm whilst that of clay was found to be 175μS/cm when corrected at a standard temperature of 25°C. This value agrees with the pH of the soil. Low and high pH values result in high electrical conductivity while pH near neutral results in low electrical conductivity (FAO 2021).

Most of the heavy metal concentrations determined were within range of the European standard threshold for soils as reported by van der Voet *et al.* 2013. However, there was high concentration of cobalt (339.9 μg/g) in the clay sample much above the threshold value (50μg/g). The concentrations of some selected heavy metals present in the soil samples determined from AAS are shown in Table 3.

Table 3. Elemental concentrations of soil sample.

	Concentration (μg/g)		
Elements	Laterite	Clay	European standard (Threshold)
Cu	22.8	24	140
Mn	329.2	172	2000
Zn	21.9	83.16	300
Co	2.0	339.6	50
Ni	55.6	55.2	75
Cd	0.8	0.8	3.0

Source: Author (2024), van der Voet *et al.* (2013).

3.3 *Mineralogical properties of the soil samples*

The results from the XRD testing of the laterite sample is indicated by X-ray diffractogram as shown in Figure 4. The dominant minerals show high peaks as shown by the X-ray diffractogram. Hematite is the mineral with the highest peak which is a typical characteristic of laterite soils. Traces of kaolinite and quartz minerals are also present.

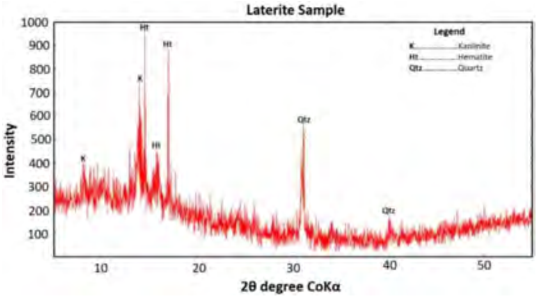

Figure 4. X-ray diffractogram of laterite sample. Source: Author (2024).

The results from the XRD testing of the clay sample is indicated by X-ray diffractogram as shown in Figure 5. The dominant mineral present in the clay sample is chlorite as shown to have the highest peak from the X-ray diffractogram which is an indication of clay mineral present in the clay soil. The non-clay minerals are biotite and quartz.

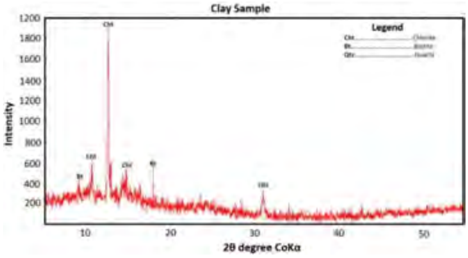

Figure 5. X-ray diffractogram of clay sample. Source: Author (2024).

3.4 *Hydraulic properties of the soil samples*

There was an increase in hydraulic conductivity as hydraulic gradient and particle size increased as indicated in Figure 6. Permeability of LS_2 and LS_3 were in the order of 10^{-9}m/s at a hydraulic gradient of 11 and 15 whilst that of LS_1 was of the order of 10^{-8}m/s. At a hydraulic gradient of 17.6, the hydraulic conductivity for LS_2 and LS_3 increased to an order 10^{-8}m/s. The hydraulic conductivity values obtained from all the three groups of laterite do not meet the standard requirement for use as a liner at hydraulic gradient above 17. The hydraulic conductivity values of CL sample measured at the various hydraulic gradients are within the order of 10^{-10}m/s. This meets the hydraulic conductivity requirement as a liner (Rowe *et al.* 1995, UK Environmental Agency 2009). The increase in hydraulic conductivity with increase in hydraulic gradient could be attributed to the increase in seepage pressure with increase in hydraulic gradient. The particle size distribution and the plasticity index control many engineering properties of soil which influence its permeability. The clay soil has a PI of 27% whilst the laterite has a PI of 17%. Though both LS_3 and CL samples were obtained by passing the bulk samples through 6.7mm BS sieve, LS_3 has high sand content (45%) whist CL contains high clay content (41%). LS_1 and LS_3 are both laterite samples but different gradation. SL_1 has high gravel and low fine content whilst LS_3 has low gravel and high fine content hence the higher hydraulic conductivity of LS_1 even at low hydraulic gradient. High plasticity index, high fine content, low gravel content and the presence of chlorite clay mineral contributed to the low hydraulic conductivity value of CL sample even

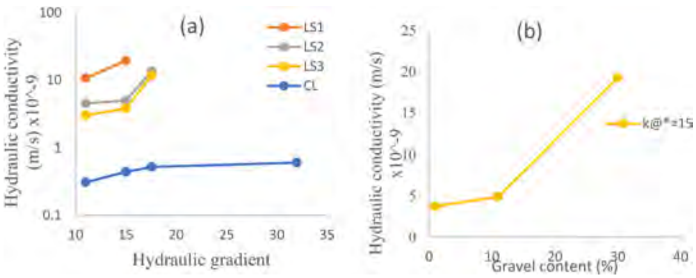

Figure 6. Variation in hydraulic conductivity with hydraulic gradient (a) and gravel content (b). Source: Author (2024).

at high hydraulic gradient. This underscore the effect of particle size, hydraulic gradient and mineralogical composition on hydraulic conductivity of compacted soil. The outcome of the laboratory determination of hydraulic conductivity of the samples at the different hydraulic gradients and different gravel contents is presented in Table 4 and plotted in Figure 6a as the effect of hydraulic gradient on hydraulic conductivity and in Figure 6b as the variation of gravel content with hydraulic conductivity.

Table 4. Permeability data for different range of particles of laterite samples.

Sample ID	Compacted density (g/cm^3)	Compacted moisture (%)	Permeability (m/s)			
			*=11	*=15	*=17.6	*=32
LS_3	1.84	17	3.0×10^{-9}	3.76×10^{-9}	1.17×10^{-8}	–
LS_2	1.82	17	4.50×10^{-9}	4.92×10^{-9}	1.35×10^{-8}	–
LS_1	1.85	14	1.06×10^{-8}	1.93×10^{-8}	–	–
CL	1.71	21	3.10×10^{-10}	4.46×10^{-10}	5.24×10^{-10}	6.06×10^{-10}

*=hydraulic gradient.
Source: Author (2024).

4 CONCLUSION AND RECOMMENDATIONS

4.1 *Conclusion*

The potential use of natural clay and laterite soil from Goma field and Shantumbu areas respectively in Zambia as liners in tailing dam construction was evaluated through laboratory study. It is observed from the study that the fine and gravel contents, mineralogical composition, and hydraulic gradient greatly influence the permeability of compacted natural soil liner. Both clay and laterite soil samples met the key parameters such as fine and gravel contents, liquid limit and plasticity index requirement of compacted soil liner. The compacted clay soil also met the hydraulic conductivity requirement. The presence of kaolinite and chlorite clay minerals further supports the natural soils for use as a liner due to the absence of excessive shrink-swell behavior of these clay minerals. Based on the results from the study, the clay soil has a potential for use as soil liner. However, the compacted natural laterite soil failed the hydraulic conductivity requirement for use as soil liner. Hence the compacted natural laterite soil may not be acceptable for use as a soil liner.

4.2 *Recommendations*

The clay soil used for this study may be recommended as a natural soil liner hence policy makers such as Zambia Environmental Management Agency (ZEMA) and The Ministry of Mines and Minerals Development (MMMD) who are the main government agencies responsible for regulating artisanal and small-scale mining ensure that small scale mining operators develop the practice of lining tailings containment with compacted natural clay. The natural laterite soil which does not meet the liner requirement must be engineered through the addition of additives to meet the hydraulic conductivity requirement of a typical soil liner.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

The adoption of circular economy to enhance sustainability within the Zimbabwean construction industry

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ABSTRACT: The study sought to examine the level of adoption of Circular Economy practices as a tool to enhance sustainability of construction projects in Zimbabwe. A questionnaire survey was employed to gather data from construction industry professionals. Based on inferential statistical analysis, the findings revealed that circularity has been marginally adopted as a tool to enhance sustainability of construction projects in Zimbabwe. The study concludes that there is a low level of adoption of circular economy practices as a tool to enhance sustainability of construction projects in Zimbabwe, hence a cause of concern. Therefore, the study recommends that policymakers, government, and construction players adopt measures which promote Circular Economy. Even though the sample size used precludes the data from being generalised without caution, the results provide insights to policymakers and key stakeholders to embrace circular economy practices to enhance sustainability of the Zimbabwean construction industry.

Keywords: Circular economy, sustainability, construction industry, adoption level, Zimbabwe

1 INTRODUCTION

The intersection of circular economy and sustainability has become a focal point for policymakers, academia, and industry as they seek to understand their interconnectedness and implications (Andersen 2007; Geissdoerfer *et al.* 2017; Rashid *et al.* 2013). Sustainability, defined as meeting present needs without compromising the ability of future generations to meet their own, emphasises the enduring support of processes over time (Brundtland World Commission Report 1987; Farley and Smith 2020). Within the business and policy spheres, sustainability efforts aim to prevent the depletion of natural resources to ensure their availability for the future (Tabara 2023).

The construction industry's significant resource consumption, accounting for substantial percentages of energy, timber, and water, poses a considerable challenge to sustainability (Ahn *et al.* 2010; Doan *et al.* 2017). The built environment's contribution to solid waste and greenhouse emissions underscores the urgency of integrating sustainable practices into construction processes (Doan *et al.* 2017; Joseph & Tretsiakova-McNally 2010). Essentially, the construction industry operates under a conventional linear model resulting in significant environmental impacts, including over 30% of global resource extraction and 25% of solid waste generation (Benachio *et al.* 2020). This is a catastrophe which requires urgent attention to prevent debilitating consequences on both the ecosystem and economies of developing countries. Mitchell and James (2015) stress the importance of prolonging resource use,

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maximising product value, and recovering materials to bolster sustainability, positioning the circular economy as crucial for sustainable development. Circular economy principles offer promising avenues for sustainable production and consumption in construction by promoting the reuse and recycling of materials, thereby mitigating waste challenges (Geissdoerfer *et al.* 2017; Lamba *et al.* 2022). The European Environment Agency (EEA 2014) highlights the circular economy's focus on recycling and reusing inputs to diminish primary resource consumption. In view of the potential benefits related to adoption of circular economy, most countries globally, are transitioning towards a circular economy to optimise material usage, curb wastage and control resource extraction (Calvo *et al.* 2014). This shift involves strategies like reusing building materials and storing components in material banks for future use (Hopkinson *et al.* 2019; Leising *et al.* 2018). The European Commission (2015) advocates for a circular economy to preserve product, material, and resource value, fostering a low-carbon, resource-efficient economy. Although circular economy principles are gaining traction, some scholars like Lacy and Rutqvist (2015) posit that their application in most countries is thwarted by lack of knowledge and relevant tools.

Chigara and Moyo (2022) reveal that the Zimbabwean context is characterised by knowledge gaps which hinder sustainability efforts. Moreover, little is known regarding the level of adoption of circular economy principles within this context. Therefore, the study sought to examine the level of adoption of circular economy practices in Zimbabwe in a bid to enhance sustainability of its construction industry.

2 CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY

2.1 *Circular economy practices*

The Circular Economy (CE) concept addresses resource scarcity and waste management, fostering a symbiotic relationship between economic growth and environmental sustainability (Homrich *et al.* 2018). Notable in the construction industry due to its substantial energy consumption and emissions, CE interventions aim to reduce energy usage and emissions, with the EU pioneering advancements like composite materials for enhanced thermal insulation (Du *et al.* 2019). Various CE frameworks, from the 3R to the 10R model, guide practices worldwide (Kirchherr *et al.* 2017). Practices such as Design for Disassembly (DfD) and Material Passport methodology exemplify proactive approaches, emphasising recyclability and material reuse (Honic *et al.* 2019). Cradle-to-cradle design and digital platforms like Building Information Modelling (BIM) enhance sustainable practices and informed decision-making throughout a project's lifecycle (Azhar *et al.* 2008; Braungart *et al.* 2006). Additionally, innovative solutions like plastic upcycling in the USA address challenges like plastic waste, contributing to circularity in construction (López-Forniés and Sierra-Pérez 2022). Eco-design and life cycle analysis play pivotal roles in integrating environmental considerations into product development within a circular economy framework (Prendeville *et al.* 2012).

2.2 *Circular economy challenges*

Transitioning to a circular economy in construction faces diverse challenges. In Zimbabwe, outdated technology and economic instability hinder waste recovery in industries like timber (Sauve *et al.* 2016). Additionally, the current economic system undervalues resources, while the high costs and risks of circular systems deter widespread adoption (Aronson *et al.* 2017; Costanza *et al.* 1987). Small and Medium Enterprises (SMEs) struggle due to limited resources and risk aversion (Moore and Manring 2009), and innovation is hampered by upfront investment costs and entrenched practices favoring low-cost materials (Agolla 2016). Regulatory inconsistencies and cultural barriers further complicate adoption (Hart *et al.*

2019). Overcoming these challenges requires collaborative efforts to foster innovation and shift towards circular practices (Katz-Gerro and Lopez Sintas 2019).

2.3 *Effective implementation of circular economy*

The effective implementation of Circular Economy (CE) principles in construction requires a thorough understanding of supply chain dynamics. This involves aligning CE principles with sustainable development goals to mitigate greenhouse gas emissions across the construction supply chain, as highlighted by Nasir *et al.* (2017). Additionally, there is a need for a paradigm shift in supply chain management towards circularity, emphasising a holistic approach to process design integrating various disciplines, as advocated by Leising *et al.* (2018). Cost management, particularly in offsite construction, plays a crucial role in waste reduction through techniques like Kaizen costing and lean construction, as demonstrated by Omotayo and Kulatunga (2015) and Arif *et al.* (2015). Circular design principles focusing on repair, recycling, and reusability during the design phase are essential for extending component lifecycles and reducing environmental impact, as highlighted by Arup and Bam (2017). Furthermore, fostering effective collaboration among stakeholders within the construction value chain is crucial for promoting circular construction practices, as emphasized by Munaro and Tavares (2023) and, Chinyio and Olomolaiye (2010).

3 RESEARCH METHODOLOGY

This study employed a quantitative approach. Quantitative research methods were deemed suitable for this investigation due to their ability to systematically collect and analyse numerical data, allowing for the examination of relationships between variables and providing insights into the adoption of circular economy practices in the construction industry (Bryman 2016). Quantitative methods were chosen to provide structured and objective insights into the factors influencing the adoption of circular economy practices within the Zimbabwean construction industry. This approach facilitated the measurement of variables related to sustainability practices, allowing for statistical analysis to identify patterns and trends in the data (Creswell and Creswell 2018). The study population was drawn from government institutions, property developers, construction companies registered with the Construction Industry Federation of Zimbabwe (CIFOZ) and professional consultants registered under the Zimbabwe Institute of Quantity Surveyors (ZIQS), Institute of Architects in Zimbabwe (IAZ), and Zimbabwe Association of Civil Engineers (ZACE), ensuring representation across key stakeholders in the construction industry in Zimbabwe. This diverse selection facilitated a comprehensive understanding of the subject matter, enhancing the validity and applicability of the research findings. Data for this study was collected using a self-administered survey questionnaire tool distributed to 70 respondents. The decision to utilise this method was based on its cost-effectiveness, scalability, and ability to reach a diverse range of respondents across different geographical locations (Babbie 2020). Additionally, self-administered surveys provided respondents with the privacy to provide candid responses, thereby minimising social desirability bias and enhancing the reliability of the data collected (Fowler 2013). To ensure the validity and reliability of the survey questionnaire tool, several measures were taken. The questionnaire was developed based on a comprehensive review of relevant literature on circular economy adoption and sustainability practices within the construction industry in Zimbabwe. Pilot testing was conducted with a small sample of industry experts to assess the clarity, relevance, and comprehensiveness of the survey items. Furthermore, reliability analysis using techniques such as Cronbach's alpha was performed to assess the internal consistency of the questionnaire items (Nunnally and Bernstein 1994).

Inferential statistics were employed to analyse the collected survey data and draw conclusions about the population based on the sample. Techniques such as regression analysis, ANOVA, and correlation analysis were used to examine the relationships between variables, identify significant predictors of circular economy adoption, and assess the overall impact on sustainability within the Zimbabwean construction industry. The specific statistical methods used may include measures of central tendency, frequency distributions and correlation analysis, to draw conclusions from the data collected through the questionnaires. These statistical methods enhanced the robustness of the findings and contributed to the generalisability of the results to broader contexts. By employing these robust methodological procedures, this study ensures the reliability, validity, and comprehensiveness of its findings, contributing valuable insights to the field of construction industry research within the context of circular economy adoption in Zimbabwe.

4 RESULTS

4.1 *Response rate*

A total of 70 questionnaires were distributed among potential respondents. From this distribution, 58 questionnaires were successfully returned by participants. Subsequently, all 58 returned questionnaires were deemed suitable for inclusion in the data analysis, because they met the study's accuracy criteria and were complete. Each of these 58 responses was carefully analysed to draw insightful conclusions and make meaningful inferences regarding the adoption of circular economy practices within the Zimbabwean construction industry.

4.2 *Demographic information of respondents*

Table 1 presents the respondents' demographic information regarding gender, organisational background, work experience and highest educational qualification.

Table 1. Demographic information of participants.

Category		Frequency	Percentage
Gender	Male	50	86
	Female	8	14
	Total	58	100
Organisational background			
	Owners (Government or Developer)	146	24.2
	Consultant		10.3
	Contractor	38	43
	Total	58	100
Work experience			
	Less than 1 year	3	5.2
	6-9 years	29	50
	6-9 years	16	27.6
	10 + years	10	17.2
	Total	58	100
Educational qualification			
	National certificate	2	3.4
	Diploma	2	3.4
	Bachelor's Degree	37	63.8
	Postgraduate	17	29.4
	Total	58	100

As shown in Table 1, most respondents were males, representing 86%, and the remaining 14% were females. The highest number of respondents had between 2 and 5 years of experience, representing 50%. The second highest number of respondents had between 6 and 9 years of experience. This is followed by respondents with experience over 10 years, representing 17.2%, and less than a year at 5.2%. Most respondents were contractors of building and civil contracting companies, represented by 65.5%. Owners (Government Institutions and Property Developers) were represented by 24.2% whilst consultants were represented by 10.3%.

4.3 *Level of adoption of CE in construction*

The adoption of Circular Economy (CE) practices in the Zimbabwean construction industry presents varying levels of acceptance and implementation. Table 2 shows the level of adoption within the Zimbabwean context.

Table 2. Level of adoption of CE practices.

CE Practice	Missing	Mean	Mode	Skewness	Rank
Eco-design and life cycle analysis	0	4.41	5	−1.159	1
Reduce, Reuse and Recycle	0	4.40	5	−1.708	2
BIM for CE	0	3.98	4	−1.046	3
Composite recycled construction material	1	3.98	5	−.502	4
Plastic Upcycling in Construction	0	3.95	5	−.744	5
Customizable Modular Unit	0	3.93	4	−.751	6
Design for Disassembly	0	3.82	4	−.799	7
Utilization of the cradle-to-cradle product registry system	0	3.65	3	−.439	8
Material Passport Methodology	0	3.63	3	−.266	9
Building deconstruction	0	3.61	4	−.609	10

From Table 2, the respondents displayed positive perception of key practices like Eco-design and life cycle analysis with a mean of 4.41, Reduce, Reuse and Recycle with a mean of 4.40, BIM for CE with a mean of 3.98, Composite recycled construction material with a mean of 3.98, Plastic Upcycling in Construction with a mean of 3.95 and *Customisable* Modular Unit with a mean of 3.93. These practices are seen as crucial for fostering friendly environments and addressing affordability challenges in housing. While respondents acknowledged the existence of practices such as Design for Disassembly, Utilisation of the cradle-to-cradle product registry system, Material Passport Methodology and Building deconstruction, their actual implementation or adoption level within the Zimbabwean context remains limited due to a myriad of factors such as the lack of legislative support and collaboration among stakeholders.

4.4 *Challenges or barriers of adopting CE practices in the construction industry*

The results of study revealed the top five challenges or barriers militating against the adoption of CE practices as economic factors with a mean of 4.23, lack of regulatory framework with a mean of 4.18, continuous accumulation of waste, with low utilization rates, with a mean of 3.91, the need for profitability with mean of 3.79 and prevalent market forces with a mean of 3.77. The respondents expressed that certain practices face challenges such as the lack of a market for recovered construction materials (e.g., building deconstruction) and high initial costs (e.g., plastic upcycling). Additionally, the implementation of Eco-design and Life Cycle Analysis is not widely adopted, primarily due to limited awareness and regulatory issues. While there is a positive sentiment toward CE practices, their implementation is frustrated by limited awareness, regulatory constraints, technological challenges, and high upfront costs. Thus, addressing these barriers will be crucial for promoting the widespread adoption of circular economy principles and enhancing sustainability within the industry. Table 3 shows the barriers of adopting CE practices in the Zimbabwean context.

Table 3. Barriers of adopting CE practices in the construction industry.

Barrier	Missing	Mean	Mode	Skewness	Rank
Economic factors	0	4.23	4	−0.670	1
Lack of regulatory framework	0	4.18	5	−0.757	2
Continuous accumulation of waste, with low utilization rates	0	3.91	4	−0.674	3
Profitability	0	3.79	4	−0.306	4
Prevalent market forces	1	3.77	3	0.071	5
Culture, competition, and firms' characteristics	1	3.64	3	−0.232	6
Lack of Time	1	3.39	3	−0.261	7
Firm Size	0	3.23	3	−0.109	8

5 DISCUSSION OF RESULTS

The results indicate a notable level of awareness of the concept of circular economy among stakeholders within the Zimbabwean construction industry. This finding aligns with previous research by Adams *et al.* (2017), highlighting existing awareness levels among construction industry actors regarding environmental, social, and economic aspects.

Furthermore, the majority of respondents associate a circular economy with principles of reducing, reusing, and recycling. This understanding resonates with literature indicating that stakeholders typically perceive circular economy concepts through the lens of regeneration and sustainable resource management (Benachio *et al.* 2020; Doan *et al.* 2017; Geissdoerfer *et al.* 2017; Lamba *et al.* 2022).

These findings present an encouraging sign for public institutions and stakeholders, suggesting an opportunity to advance the circular economy agenda within the construction sector. However, a noteworthy insight from the study underscores the necessity of extending awareness of circular economy principles beyond industry stakeholders to the entire public procurement supply chain. This expansion of awareness could foster greater alignment and integration of circular economy practices throughout the construction industry's broader ecosystem as suggested by Leising *et al.* (2018).

The results show the crucial role of supply chain integration in fostering the adoption of circular economy practices within the Zimbabwean construction industry. Participants emphasize that sustainable procurement practices play a pivotal role in enhancing circularity in construction activities. Moreover, respondents advocate for public procurement policies that mandate suppliers to engage in activities that promote a circular economy, reflecting a growing recognition of the need for systemic changes to drive sustainability.

These findings align with existing literature, which suggests that public procurement initiatives have a positive impact on circular consumption patterns. Studies such as that by Kristense *et al.* (2021) highlight the potential of public procurement to promote closed material loops and value retention through the reuse of products and materials in a circular manner. Such initiatives are essential for fostering a transition towards more sustainable and circular practices within the construction sector.

The findings underscore that the practical implementation of circular economy principles predominantly involves enterprises, highlighting the pivotal role of businesses in driving adoption. Moreover, the results highlight the necessity for legislative frameworks and effective supervision to facilitate the successful implementation of circular economy practices. Specifically, the study reveals that the activities of most Small and Medium-sized Contractors (SMCs) have significant environmental implications, primarily stemming from construction activities. Therefore, there is a pressing need for regulatory measures to mitigate environmental damage and curtail resource consumption associated with construction operations.

These findings align with existing literature, which emphasises the substantial environmental impact attributed to construction and demolition waste. Indeed, studies such as that by Ghisellini *et al.* (2018) corroborate the notion that construction-related waste constitutes a significant portion of environmental pollutants.

6 CONCLUSION

The study sheds light on the adoption of Circular Economy (CE) practices and the challenges encountered within the Zimbabwean construction sector, aiming to enhance sustainability through a circular economy framework. While industry stakeholders demonstrate awareness of the circular economy concept, the study emphasises the need to extend this understanding throughout the supply chain to ensure effective implementation. A notable barrier identified is the absence of a regulatory framework tailored to circular practices, hindering their widespread adoption. Moreover, market volatility and high upfront costs emerge as significant deterrents for industry players considering circular practices. For instance, SMCs are identified as pivotal in implementing circular economy principles through innovative construction methods that minimise resource consumption and environmental impact. The research underscores the necessity for collaborative efforts between public institutions and industry actors to establish and transition towards a circular economy model. It advocates for extending awareness of circular economy principles beyond theoretical understanding to practical implementation across all involved stakeholders. Furthermore, the findings offer valuable insights to policymakers and practitioners regarding mechanisms to improve the adoption of Circular Economy practices. The study recommends that policymakers design procurement policies that incentivise and promote circular economy practices within the construction sector. Considering the scant literature that focused on the adoption of circular economy in Zimbabwe, this groundbreaking study emphasises the importance of collective action and policy support in realising the potential benefits of a circular economy for sustainable construction practices in Zimbabwe. Despite the valuable insights offered by the results, their generalisability could be limited by the adopted sample size and a mono method quantitative approach. Hence, future research could consider a larger sample size and mixed method approach to get more insights regarding the adoption of Circular Economy in Zimbabwe and the Global South.

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Innovations in bacterial concrete for sustainable structures: Challenges and prospects

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ABSTRACT: This review emphasizes the importance of bacteria in self-healing concrete for sustainable construction practices. Concrete faces environmental interactions that result in higher maintenance costs and sustainability issues. The bacterial-induced calcite precipitation process, triggered by the enzymatic hydrolysis of urea, enables the formation of calcium carbonate crystals. This improves the mechanical and durability properties of concrete, ultimately extending its lifespan. Ensuring the compatibility of bacteria in concrete is crucial and can be influenced by various concrete admixtures, such as superplasticizers, accelerators, and the activity of bacterial spores. Collaborative efforts among researchers and stakeholders are necessary to address challenges like scalability, durability, and standardization. Optimizing bacterial concrete for various applications, integrating genetically modified bacteria into the concrete mixture, adopting sustainable manufacturing techniques, and employing smart technologies to diagnose the early signs of damage are crucial. In addition, future research directions promise to revolutionize concrete to enhance performance and promote sustainability.

Keywords: bacterial concrete, calcite precipitation, sustainability, self-healing, bacterial role

1 INTRODUCTION

Sustainability in concrete is a critical focus area in the construction industry due to its environmental impacts and long-term viability. Concrete's carbon footprint and resource consumption have been raising much of concerns (Naik 2020). Extracting natural resources for concrete production, such as aggregates and water, also presents challenges related to habitat destruction and resource depletion (Desai 2017; Gomes da Silva *et al.* 2020). Sustainable concrete structures aim to minimize societal impact throughout their life cycle by using environmentally friendly materials and promoting energy efficiency (Danso 2018; Naik 2008).

Concrete is a widely used construction material known for its high compressive strength and compatibility with reinforcing steel (Seifan 2018; Seifan *et al.* 2016). However, concrete is prone to various forms of damage, resulting in structural or non-structural cracks that reduce its durability (Amiri *et al.* 2018) and longevity. Reinforcement corrosion is a significant factor affecting concrete (Jakhrani *et al.* 2019), especially in aggressive weather zones. The Common causes of concrete cracks include temperature variations including freeze-thaw cycles (Mahmoodi & Sadeghian 2019), in addition, both drying and autogenous shrinkage can affect concrete at an early age (Holt and Leivo 2004). Sustainable practices are gaining importance in various forms in civil engineering and other industries. By the year 2035 and beyond, technologies like carbon capture, storage, and green hydrogen will require significant support to reduce carbon emissions (Chao 2023; Patil *et al.* 2022). Alternative binders, such as geopolymers and calcium sulfoaluminate cement, are being utilized to offer

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environmental benefits compared to conventional Portland cement (Scrivener *et al.* 2018). Current concrete treatment methods for crack repair, like the use of chemicals and polymers, have been shown to pose health and environmental risks and may only be effective for short periods. A microbial self-healing approach is known for its potential in rapid and active crack repair, as well as its environmental friendliness (Seifan *et al.* 2016). The majority of the annual construction budget is allocated to rehabilitating and repairing existing concrete structures (Cailleux and Pollet 2009). Recent advancements in microbiology, materials science, and civil engineering have contributed to research efforts to fully utilize bacterial concrete in various applications. The use of genetically modified bacteria to enhance crack healing in concrete structures has significantly improved efficiency and long-term durability. Self-healing concrete has gained attention due to its ability to extend the lifespan of infrastructure, reduce maintenance costs, and enhance sustainability (Sarkar *et al.* 2023).

Bio-based bacterial concrete, made from renewable resources such as offers an eco-friendly alternative to conventional concrete by leveraging bacteria's self-healing capabilities to produce calcium carbonate, which effectively seals cracks, improves durability and reduces maintenance costs (Hussein *et al.* 2019; Vera *et al.* 2021) and maintenance frequency. Self-healing approaches in concrete can be categorized as autogenous healing and autonomous healing. Autogenous healing occurs naturally through further hydration of unhydrated cement in concrete, while autonomous healing requires a trigger to be activated, such as by microbial action (Zhang W. *et al.* 2020). However, both methods can only repair cracks within a few hundred micrometers and are unsuitable for significant damage. There is research regarding bio-bacterial concrete with its potential to enhance sustainability and durability in construction. However, there are several limitations and research gaps that need to be addressed. One major challenge is the lack of long-term performance data, which hampers our understanding of how the material behaves over decades in different environmental conditions. Another challenge is scaling up production to an industrial level while maintaining bacterial viability and effectiveness. In addition, challenges such as dosage and standardization need to be addressed for widespread adoption in construction (Hussein *et al.* 2019). The focus of this review is to discuss bio-based bacteria in what is known as self-healing concrete. The objectives are to:

- Explore the role and mechanism of bacteria in concrete using bacterial-induced calcinated precipitations.
- Provide insights into the present challenges, and future research and promote the implementation of bio-based bacterial concrete for sustainable development.

2 METHODOLOGY

It is important to follow a systematic approach to achieve the objectives of a review article. The process begins by defining the objectives and scope of the review, which guides the selection of articles. A literature search uses databases such as PubMed, Google Scholar, and Scopus. Search terms are tailored to match the review's focus, and filters are used to refine the results. The timeframe for inclusion is determined based on the topic, including recent publications. Each selected article is evaluated for relevance, contribution to the discussion, insights, and novel findings. Key information from the selected articles is extracted, including findings, methodologies, conclusions, and other relevant details. The gathered information is analyzed to identify patterns, themes, contradictions, and gaps in the literature.

3 PRINCIPLES OF BIO-BASED BACTERIAL CONCRETE

3.1 *Role and mechanism of bacterial-induced calcite precipitation*

Bacterial-induced calcite precipitation (BICP) is a fascinating biomineralization process in which certain bacteria plays a crucial role in precipitating calcium carbonate ($CaCO_3$)

minerals (Baidya *et al.* 2023). This mechanism has garnered significant attention due to its potential applications in various fields, including construction, environmental remediation, and biotechnology (De Muynck *et al.* 2008). The process of BICP involves several key mechanisms that facilitate the precipitation of calcite by bacteria. Production of urease enzymes by uratolytic bacteria, such as Sporosarcina pasteurii is one of the mechanisms. Urease catalyzes the hydrolysis of urea present in the surrounding environment, leading to the production of ammonium ions and carbonate ions. These carbonate ions trigger the precipitation of calcium carbonate from the solution, forming calcite crystals (Achal *et al.* 2011). This enzymatic hydrolysis of urea serves as a fundamental driver for BICP in many applications (Martinez *et al.* 2013).

Bacteria can create micro-environments with elevated pH levels and high concentrations of calcium and carbonate ions, which are conducive to the nucleation and growth of calcite crystals (Phillips *et al.* 2013; Stocks-Fischer *et al.* 1999). Micro-organisms such as Bacillus Subtilis and chemically modified Bacillus subtilis induced calcinate and silica precipitation. First, it was prepared by reacting with ethylenediamine to modify its cell wall to become electropositive facilitating the binding of the silicate during the incubation process (Afifudin *et al.* 2011). The cell surface of bacteria provides sites for the heterogeneous nucleation of calcite crystals, facilitating the formation of calcite coatings or aggregates around bacterial cells (DeJong *et al.* 2010). Additionally, the interaction between bacterial cells and calcium carbonate minerals offers the potential for the immobilization of contaminants in environmental remediation applications (Achal *et al.* 2011). Metabolic organic compounds result in improved properties in concrete, such as enhanced compressive and flexural strengths, and increased durability (De Muynck *et al.* 2010; Jonkers *et al.* 2010). The autonomous healing mechanism not only prolongs the service life of concrete structures but also reduces the need for frequent maintenance and repair, thereby enhancing sustainability (Cappellesso V. *et al.*). Autonomous methods of bacteria are utilized to facilitate the precipitation of calcium carbonate ($CaCO_3$) in the presence of calcium ions and carbonate ions. This process occurs primarily due to the metabolic activities of the bacteria, which create conditions for the precipitation of calcium carbonate according to the following equations (Choudhary 2020), which is considered as precipitation of a wide range of minerals by bacteria, known as biomineralization (Rajasekar *et al.* 2021)

$$Ca^{2+} + \text{cell} \rightarrow \text{cell} - Ca^{2+} \rightarrow CO3^{2-} \rightarrow \text{cell} - CaCO_3 \tag{1}$$

The enhanced carbonate ion production resulting from urea hydrolysis can promote crack filling and self-healing in materials like concrete, the production of ammonium ions and the limited lifespan of the bacteria present challenges that need to be addressed for practical application. The reaction mechanisms of urease bacteria are given by (Baidya *et al.* 2023; Hazarika 2021) as follows:

$$CO(NH_{22(\text{Urea})}) + H_2O \rightarrow NH_2COOH + 2NH_3^{+} \tag{2}$$

This is a process of changing urea into ammonia using urease as a catalyst.

$$NH_2COOH + H_2O \rightarrow NH_3 + H_2CO_3 \tag{3}$$

$$H_2CO_3 \rightarrow 2CO_3^{2-} + 2H^{+} \tag{4}$$

$$NH_3 + H_2O \rightarrow NH_4^{+} + OH^{-} \tag{5}$$

The net product of CO_3^{2-} and NH_4^{+} are very important, the carbonate can attach with the Ca^{2+} to form calcinate ($CaCO_3$) which can be facilitated by OH^- for precipitation. In addition, ammonium ion is alkaline which can enhance the pH value of concrete which is critical to passivation conditions. Furthermore, the application of bacteria for concrete enhancement aligns with the principles of environmental sustainability. By utilizing biological processes, MICP reduces the reliance on normal concrete repair and minimizes the environmental impact associated with their production and disposal. This eco-friendly approach to concrete construction offers a promising solution for enhancing infrastructure resilience while mitigating the ecological footprint of construction activities (Van Tittelboom *et al.* 2010).

3.2 *Compatibility of bacteria to concrete constituents*

Bacterial concrete is becoming increasingly popular due to its ability to self-heal cracks, which has recently garnered significant attention. These bacteria cause water seepage towards the cracks in concrete to produce calcite or other mineral deposits that help seal them (Bandlamudi *et al.* 2023). However, to fully harness the benefit of this technology, it is crucial to assess how well bacterial agents work with conventional concrete ingredients (i.e., cement, aggregates, water, and admixtures). Therefore, it is necessary to evaluate bacterial survival, metabolic activity, and the effectiveness of fracture healing within the concrete matrix. The compatibility of bacterial agents with conventional concrete ingredients has been studied to ensure optimal performance and longevity of bacterial concrete. Various concrete admixtures, such as superplasticizers, accelerators, and the viability and activity of bacterial spores, influence the compatibility of bacteria (Jonkers *et al.* 2010). Certain admixtures, especially those containing high concentrations of calcium ions, can inhibit bacterial activity. However, careful selection of admixtures and concentrations can maintain the functionality of the bacterial agents.

Furthermore, the porosity and surface properties of the aggregate affect bacterial colonization and subsequent crack healing. Therefore, different aggregates, such as limestone and recycled concrete aggregates, have an impact on bacterial activity and crack healing efficiency (Amran *et al.* 2022). Therefore, understanding these interactions is essential for optimizing the performance of bacterial concrete in various construction applications. Additionally, chemical admixtures used to enhance concrete properties, such as corrosion inhibitors and waterproofing agents, influence bacterial spore germination and mineral precipitation (Luhar *et al.* 2022). Overall, ensuring the compatibility of bacterial agents with the ingredients of conventional concrete is crucial for the successful implementation of self-healing concrete technology. By addressing these compatibility considerations through careful selection and optimization of concrete mixtures, the potential of bacterial concrete to enhance the durability and sustainability of infrastructure can be fully realized. The role, mechanism, and compatibility of bacteria in concrete are summarized in Table 1 below:

Table 1. Summary of role, mechanism, and compatibility of BICP,

Principles	Descriptions
Mechanism	The urease enzyme catalyzes urea hydrolysis, producing carbonate and ammonium ions to promote calcite crystal nucleation and higher pH value in concrete. Bacterial cell surface acts as sites for heterogeneous nucleation of calcite crystals. Interaction between bacterial cells and calcium carbonate minerals for aggregate formation
Role	Facilitation of calcium carbonate precipitation through metabolic activity and cell surface Enhancement of concrete properties like Strength and durability and crack healing Participation in environmental remediation processes by immobilizing contaminants Consuming O_2 and using CO_2 for calcite formation

(*continued*)

Table 1. Continued

Principles	Descriptions
Compatibility	Bacterial survival and metabolic activity in the concrete matrix influence the effectiveness. Concrete admixtures influence bacterial activity in concrete Aggregate properties on bacterial colonization and crack healing efficacy Compatibility of chemical additives with bacterial spore germination and mineral precipitation

3.3 *Practical application of Bio-concrete*

The practical application of bacterial concrete is in infrastructure, historical structural repair, concrete pavement applications, and building constructions. Bio-based bacterial concrete has been shown to outperform conventional concrete in terms of resistance to chemical attack, freeze-thaw cycles, and chloride ingress. This leads to a longer service life and reduced maintenance requirements (V. G. Cappellesso *et al.* 2023).

Studies have found that the production and use of bacterial concrete results in reduced carbon emissions, energy consumption, and resource depletion compared to conventional concrete, contributing to overall environmental sustainability (Ramagiri *et al.* 2021). Field evaluations have demonstrated that bacterial concrete effectively repairs cracks, improves durability, and extends the service life of concrete structures, leading to cost savings and sustainability benefits (Dong *et al.* 2023). Numerous performance evaluations and studies have highlighted the effectiveness of bio-based bacterial concrete in areas such as self-healing, durability, mechanical properties, environmental sustainability, and real-world applications.

4 PROSPECTS, CHALLENGES, AND RESEARCH DIRECTIONS

Innovative materials can autonomously repair cracks, improving the durability and longevity of infrastructure systems. Novel microbial technologies are being explored to optimize the performance of bacterial concrete in real-world scenarios (Zhang Z. *et al.* 2019). Studies have also investigated alternative nutrient sources, fermentation processes, and manufacturing techniques to enhance the sustainability of bacterial concrete (Raza *et al.* 2023). Another area of research is the integration of smart materials and sensor technologies into bacterial concrete. By incorporating sensors and actuators, researchers aim to create self-diagnostic systems capable of monitoring structural health and detecting early signs of damage (Maurya *et al.* 2020). Research direction focuses on optimizing the healing efficiency of bio-concrete by exploring different bacterial strains and their ability to produce calcite. Identifying bacteria that are highly effective at precipitating calcium carbonate can enhance the speed and effectiveness of crack repair mechanisms (Wiktor and Jonkers 2011).

Another key research direction is the durability and longevity of bacterial concrete under various environmental conditions. Available literature lacks studies on the performance of bio-concrete in terms of resistance to factors such as freeze-thaw cycles, chemical exposure, and mechanical loading (Snoeck *et al.* 2014). Challenges also exist in the scalability and production of bacterial concrete for large-scale construction applications. Developing cost-effective methods for mass-producing bacteria and incorporating them into concrete mixes on an industrial scale is crucial for commercial viability (Achal *et al.* 2013). This includes ensuring the uniform distribution of bacteria within the concrete mix, optimizing the nutrient composition to support bacterial growth, and controlling environmental factors such as temperature and moisture to promote effective biomineralization (Maste 2018). Standardization and regulatory frameworks are also essential to ensure the quality, safety, and reliability of bacterial concrete in construction applications. This involves establishing standardized testing protocols and industry guidelines to support the widespread adoption of bio-concrete technology (Van Mullem *et al.* 2020). Collaboration between researchers, industry stakeholders, and regulatory bodies is critical to accelerate the development and commercialization of bacterial concrete products. Overall, the prospects and research directions of bacterial concrete offer significant promise for the construction industry. With advancements in microbial technology, sustainable manufacturing practices, and smart material integration, bio-concrete is poised to design and maintain infrastructure systems. Table 2 summarizes the research focus, recent progress, challenges, and future research on bacterial concrete.

Table 2. Prospects and research directions of bacterial concrete.

Focus	Recent Progress	Challenges	Future Research Directions
Bacterial Strain Selection	Identification of novel bacterial strains with enhanced calcite precipitation capabilities.	Ensuring compatibility of bacterial strains with concrete mixtures.	Explore bioengineering approaches to enhance the properties of bacterial concrete, including genetic modification of bacteria for improved calcite-producing capabilities in harsh environments
Bio-mechanism	Understanding the molecular mechanisms of Bacterial calcium carbonate precipitation	Lack of understanding of complex microbial processes.	Integrating diverse approaches to unveil the intricate mechanisms governing mineral formation/ biomineralization by microbial communities.
Durability, Enhancement	Demonstration of enhanced resistance to chemical and physical deterioration in bacterial concrete.	Difficulty in scaling up production. Limited repair for structural damage beyond a hundred μm	Developing standardized protocols for large-scale production and application. Establish standards and regulations specific to bacterial concrete to ensure quality control and safety
Envi. Sustainability	Reduced carbon footprint and waste reduction potential of bacterial concrete.	Concerns regarding long-term environmental impacts and biocom patibility.	Conducting life cycle assessments and addressing potential ecological risks associated with bacterial concrete.
Structural Performance	Evaluation of mechanical properties and structural integrity of bacterial concrete.	Variability in performance due to environmental conditions and material composition.	Implementing advanced testing methods to optimize performance under different conditions. Integrating bacterial concrete with smart technologies for real-time monitoring and controlling of the healing process by embedding sensors and actuators within bio-concrete structures
Cost-effectiveness	Identification of cost-saving potential through reduced maintenance and increased lifespan.	Initial high costs with bacterial concrete production and application.	Investigating cost-effective production methods and exploring potential subsidies or incentives for adoption.

5 CONCLUSION

The review article highlights significant advancements in sustainability within the construction industry facilitated by bio-based bacterial concrete. The following conclusions are drawn:

- Bio-based bacterial concrete holds significant potential to promote sustainable development in construction, marking a crucial step towards a greener and more resilient built environment.
- The mechanism of bacterial-induced calcite precipitation, with the net products of CO32- and NH4+. The carbonate can attach to the Ca2+ to form calcite (CaCO3), which can be facilitated by OH- for precipitation and ammonium ion is alkaline, which can enhance the pH value of concrete which is very important for concrete staying in passivation conditions.
- Bio-based bacterial concrete effectively reduces the carbon footprint by minimizing reliance on energy-intensive cement production and the utilization of organic waste materials.
- Ongoing and future research should focus on optimizing bacterial strains, improving sustainability, integrating smart technologies, addressing scalability challenges, and standardization with regulatory frameworks to ensure the utilization of bio-concrete.

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Exploring the multifaceted impacts of 3D printing in Malawi: A case study analysis

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ABSTRACT: 3D Printing has been recognized as a transformative technology in the construction field, capable of rapid and efficient building processes. This research focuses on the impacts of this technology in the Malawian construction industry, where infrastructure gaps in education, and housing are persistent. The study employed a qualitative approach, interviewing eight (8) key stakeholders involved in three (3) 3D printing projects. The findings indicate that this technology can significantly reduce construction time and material waste. Despite these benefits, challenges such as high initial costs and reliance on external consultants for setup and training require attention. The study recommends local production of 3D printing materials, promoting skills development, and fostering collaboration among industry stakeholders and government bodies. This research contributes to understanding 3D printing's potential in Malawi, emphasizing its role in sustainable development and addressing the country's need for sustainable construction while offering insights for policymakers on regulatory and investment strategies.

Keywords: Construction Industry, 3D Printing, Malawi, Sustainable Development, Impacts

1 INTRODUCTION

In 2015, the United Nations (UN) established seventeen (17) Development Goals (SDGs) as a replacement for the Millennium Development Goals (MDGs). The purpose of these goals is to eliminate poverty while preserving the environment by the year 2030 (UN 2015). A crucial element of these SDGs is fostering environments through innovative infrastructure initiatives (UN 2015). Multiple nations, including Malawi, have committed to achieving these goals by implementing strategies such as Malawi 2063, to combat poverty and inequality (Kampanje 2023). To achieve this vision, numerous milestones were set, including the construction of essential infrastructures like housing, schools, water facilities, sanitation systems, roads, parks, etc., to promote sustainable human settlements (Kampanje 2023). Regrettably, despite these efforts, the urban poor population continues to grow in many developing nations like Malawi due to the swift urbanization prevalent in recent times (Braka 2024; World Bank 2019).

Unicef (2019) estimates a shortfall of 36,000 primary school classrooms, a gap that would require 70 years to address using traditional construction methods. These conventional methods not only fail to provide sufficient infrastructure for quality education but also lag in meeting enrolment demands. Zuka (2024) reveals the necessity for approximately 21,000 new housing units each year for the next decade to meet housing needs, surpassing the current supply. In urban regions, many people reside in slums marked by inadequate water and poor housing and sanitation facilities, lack of electricity, and poor road networks (World Bank 2019). World Bank (2019) further points out that Malawi is grappling with rapid population growth, leading to severe

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environmental degradation, infrastructure deficiencies, food and water insecurity, and persistent poverty.

The compounding challenges have been exacerbated by the disruption of infrastructure due to adverse weather conditions such as the cyclone Freddy that occurred in 2023. Braka (2024) underscored that a total of 624 schools across 22 education districts were affected by the cyclone, with a total of 724,709 learners being forced out of school. The disruption of essential infrastructure necessitates immediate reconstruction. Malawi Government has put in place the Disaster Risk Management Act of 2023 while stressing the importance of "building back better," falls short in addressing the fast reconstruction of resilient and quality houses. Nonetheless, the conventional approaches are sluggish in the rebuilding process, with a full reconstruction expected to stretch over five years, as evidenced by the recent cyclone incident - a timeframe that exposes communities to prolonged periods of vulnerability (Government of Malawi [GoM] 2023). The expected cost for the recovery and rebuilding efforts in Malawi after Cyclone Freddy in 2023 is $680.4 million (GoM 2023). This causes a severe negative impact on the already struggling economy of Malawi. The government has further introduced initiatives like the National Construction Industry Development Act of 2016 and the Building Standards Act of 2018 to enhance Malawi's construction capabilities and efficiency, but the desired outcomes have not been achieved (Mfune 2021).

It is evident from these prevailing challenges that, conventional construction methods are becoming insufficient. To solve these challenges, Malawi has the chance to use advanced technologies from the Fourth Industrial Revolution (4IR) such as artificial intelligence (AI), automation, the Internet of Things (IoT), and additive manufacturing (3D printing). This confluence of technology creates opportunities for the development of infrastructure, allowing for the use of efficient and sustainable building methods (Aghimien 2021).

3D Printing technology has the potential to reduce the time required to alleviate classroom shortages in Malawi from 70 years to 10 years (New Atlas 2021). This showcases a potential solution to address the prevailing infrastructure gaps in Malawi. Additionally, 3D Printing methods reduce carbon emissions, and material waste due to the absence of formwork (Kronast 2021). It is evident that additive manufacturing could ensure a more efficient and sustainable construction industry in Malawi. Although the potential benefits of 3D printing in Malawi's building sector seem promising, there is little to no research on its impact in the Malawian context. This research seeks to address the disparity by investigating the ecological impacts of integrating 3D printing technology into building practices in Malawi. Understanding the benefits of manufacturing is crucial in the current situation as the country seeks ways to address its infrastructural problems. This project aims to provide insights into how 3D printing might improve cost-effectiveness, productivity, speed, and sustainability in building procedures. The ultimate purpose of this research is to provide a foundation for transforming the construction industry and contributing to the accomplishment of development goals. The justification for this research lies in its potential to offer sustainable and rapid construction solutions, addressing critical infrastructural deficits in Malawi and providing valuable insights for policymakers on regulatory and investment strategies.

2 MATERIALS AND METHODS

This research employed a multiple-case study design to explore the social, environmental, and economic impacts of 3D printing in the Malawian construction industry. The study focused on multiple case studies from real-time building projects. This approach allows for in-depth examination and comparison across different construction contexts, enhancing the robustness of the findings (Zainal 2019).

2.1 *Case study selection*

Three case studies were chosen for this study including; a 40 m2 printed residential house in Lilongwe, and an Early Childhood Development Center in Phalombe (ECDC) comprising of a kitchen area and two more rooms. The final case study is the school in Salima, recognized as the world's first 3D Printed school (14Trees 2021). These projects were selected for their representation of diverse construction settings and their pioneering use of 3D printing technology to address infrastructure needs in Malawi. Malawi was selected due to its infrastructure difficulties, such as a lack of classrooms, housing shortages, and the necessity for post-disaster rebuilding. Furthermore, Malawi is one of the countries leading the way in 3D printed construction in Africa offering a pertinent setting, for exploring the impacts of 3D printing technology.

2.2 *Data collection*

Semi-structured interviews were selected as the primary data collection method for this study. This method aids in gaining a profound understanding of participants' perspectives, values, and processes related to a concept, leading to comprehensive data collection (Sumanasiri 2020). This method was deemed suitable for capturing the viewpoints of stakeholders involved in additive manufacturing projects within Malawi.

2.3 *Participants*

Key specialists engaged in the building of the 3D Printing projects were interviewed. The interviewers consisted of the managing director, civil engineer, construction foreman, quality assurance specialist, quantity surveyor, technical consultant, operator, and project manager. The selection of these individuals was based on their extensive expertise in the study field and their practical involvement in 3D Printing initiatives.

2.4 *Sample size*

The sample size of this research was 8 participants, which was chosen based on the principle of data saturation which was recommended by Guest *et al.* (2006) who suggested that 8 to twelve (12) participants is deemed sufficient to achieve data saturation. Data saturation occurs when no new information or themes emerge from the data, indicating that further sampling is not going to yield additional meaningful insights to the study (Guest *et al.* 2006). Therefore, a sample size of 8 was considered appropriate for this study, allowing a thorough examination and analysis of the different processes and real-time data of the case studies to achieve the research objective.

2.5 *Data analysis*

Thematic analysis was chosen for data analysis due to its suitability in examining qualitative data. This method offers a systematic approach to analyzing qualitative data, and identifying patterns, themes, and connections within the data (Lester 2020). By coding and analyzing data thematic, analysis allows the extraction of meaningful insights aligning with the study's goal. Moreover, this method provides flexibility, in identifying emerging themes to ensure an examination of all aspects of the data and contribute to a comprehensive investigation of the research objective (Majumdar, (2019).

Ethical Considerations: Ethical measures were adopted in this study. All participants were informed about the study's objectives. Confidentiality was maintained throughout the research process to ensure the privacy of participants.

3 RESULTS AND DISCUSSIONS

This study dwells on the perspectives of participants involved in 3D Printing projects. It presents key findings from interviews, offering insights on the implementation of additive manufacturing technology.

3.1 *Background information*

Table 1 shows participants, coded from P1 to P8, consisted of professionals with a mix of experience levels, including the managing director, site engineer, construction foremen, quality assurance specialist, quantity surveyor, technical consultant, 3D printing operator, and project manager. Table 1 summarizes the roles of the participants and their years of experience.

Table 1. Participants and their years of experience in the construction sector.

Participant Code	Role	Years of Experience
P1	Managing Director	3 years
P2	Civil Engineer	10 years
P3	Construction Foreman	12 years
P4	Quality Assurance Specialist	8 years
P5	Quantity Surveyor	6 years
P6	Technical Consultant	3 years
P7	Operator	2 years
P8	Project Manager	(1) years

3.2 *Participants perspective*

The table, below summarizes the perspectives of individuals engaged in three different case studies in the construction sector of Malawi highlighting the significance of printing technology. The table organizes feedback based on categories using "P" for positive "N" for negative "D" for debatable and "N/A" for no response. These case studies provide insights into how 3D printing can address issues like infrastructure gaps, housing shortages, and post-disaster recovery efforts in Malawi. By exploring the perspectives of participants this table offers an examination of the impacts of incorporating 3D printing technology into construction endeavors, within the Malawian setting.

Table 2. Key variables.

Key Variable	P1	P2	P3	P4	P5	P6	P7	P8
Less Construction Time	P	P	P	D	D	P	P	P
Address Infrastructure Gap	P	P	P	P	P	D	P	P
Skills Development	P	D	D	P	D	P	D	P
Post-Disaster Solutions	P	P	P	P	D	D	P	P
Reduction in CO2 Emissions	P	P	P	P	P	P	D	P
Reduced Material Usage	P	P	P	P	P	P	P	P
Energy Efficiency	D	P	D	P	P	P	P	D
Construction Cost Reduction	P	P	P	D	P	D	P	P
High Initial costs	D	D	N	P	D	D	D	D
Integration of Local Material	P	P	P	D	P	P	P	D
Resilient Infrastructure	P	P	P	P	P	D	P	P

The findings of the case studies conducted in the construction sector of Malawi reveal the perspectives of interviewees towards 3D printing technology. The majority of participants expressed views regarding the reduced construction time filling infrastructure gaps and lowering CO2 emissions. Specifically in instances like the construction of schools in Phalombe and Salima as well as the urban housing development in Lilongwe respondents consistently observed that 3D Printing significantly decreased construction time and expenses. Nevertheless, there were some opinions ("D" for debatable) raised, especially concerning skill enhancement and the financial burden of printers. Some participants suggested that while 3D printing offers benefits challenges remain with regard to training and high initial costs. In essence, these findings indicate that although 3D printing holds promise, for transforming construction practices further exploration is necessary to overcome the identified hurdles.

3.3 *Thematic analysis*

The study consolidated its results into thematic categories, examining the social and economic impacts of integrating 3D printing technology into the construction sector, in Malawi.

3.3.1 *Social impacts*

3.3.1.1 *Addressing the educational gap* P3 and P4 stated that the school in Salima and the ECDC were completed in just 18 hours and 23 hours respectively in contrast to the lengthy period required for construction using conventional methods. Additive manufacturing initiatives substantially reduce construction duration, these findings align with that of Ayub *et al.*, (2018) who suggested that timely delivery of infrastructure is the major benefit of 3D Printing this far. Malawi is facing a shortage of 36,000 classrooms as projected by UNICEF (2019), a gap that would take 70 years to fill. According to 14Trees (2022), this would take only 10 years to achieve whilst using additive manufacturing. Rapid delivery of schools not only contributes to quality education for children in Malawi but also mitigates issues related to overcrowding. According to (Hakaya *et al.* 2020), children who learn in crowded spaces have a high risk of suffering from severe health conditions such as respiratory diseases and infectious diseases. Therefore, 3D Printing technologies can contribute to quality educational environments, contributing to the well-being of Malawian students.

3.3.1.2 *Addressing housing gaps* The construction of a 40 square meter home utilizing 3D printing technology in Lilongwe was accomplished within only 12 hours, although conventional building techniques would generally take several days to finish such a structure (P6, P7, P8). These results align with the research conducted by Ajiboro (2022), which demonstrates that using conventional building techniques in Kenya, such as utilizing earth-compressed bricks for the same design and floor space, would require around two weeks, resulting in a reduction of construction time of 96.42% as it took only 15- 18 hours to construct the house with the COBOD printer. Adopting more effective building methods could contribute to alleviating Malawi's severe housing shortage, as shown by Habitat's projection in 2017. The study revealed that the present construction procedures are unable to satisfy the yearly demand for 21,000 housing units. 3D-printed dwellings may alleviate housing shortages and provide housing options for urban populations in demand.

3.3.1.3 *Skills development* Projects using 3D printing may need a smaller workforce in comparison to traditional methods. Nevertheless, these programs provide chances to improve skills in a labor market that is mostly factory-based, hence increasing possibilities for future employment. Transitioning from on-site to off-site construction has the potential to result in improved safety conditions and the creation of secure, factory-based employment opportunities (P8). This transformation is significant for the construction labor market as it provides more work stability and opportunities for skill development, as compared to time-limited construction occupations that provide little job security (Ntakana and Alabi 2022).

3.3.1.4 *Post-disaster solutions* Malawi faces disasters impacting a large number of individuals and various essential facilities, like schools, homes, and healthcare centres each year. According to a report by the World Bank in 2019 over 100,000 people are affected annually. The utilization of 3D printing technology emerges as an effective solution for rebuilding disaster infrastructure enabling quick restoration and shortening the recovery period significantly (P4, P6). Following Cyclone Freddy in 2023 the estimated five-year reconstruction plan reported by Braka (2024), this timeline could potentially be halved with the adoption of printing innovations. The prompt deployment of shelters and housing post-disaster plays a role in safeguarding displaced individuals from health risks, adverse weather conditions and other dangers thus facilitating the recovery process (Subramanya *et al.* 2021). This aligns with the findings by Subramanya *et al.* (2021) which indicate that 3D Printing technology could be a significant aid to for post recovery initiatives.

3.3.2 *Environmental impacts*

3.3.2.1 *Reduction in CO2 emissions* One of the vital benefits of 3D printing is its reduction in carbon dioxide emissions when compared to construction methods. P8 stated that there was a notable decrease in CO2 emissions where life cycle assessments were conducted of about 65%. A project report conducted by Mapei in 2021 revealed a decrease of 50% to 70% in CO2 emissions from the Lilongwe and Salima projects. These findings are consistent with research by Alami *et al.* (2023) underscoring how 3D printing holds promise for transforming construction practices by significantly lowering carbon footprints. This reduction aligns well with Malawi's sustainability goals and eco-friendly initiatives such as the Pop 60 program that promotes carbon reduction efforts and sustainable approaches, within the industry.

3.3.2.2 *Reduced material usage* P1, P2, and P8 underscored that 3D printing on the projects minimized wastage and pollution levels by around 70%. This aligns with Aleksandra (2018) underscoring that through reduced formwork and optimized material usage, this approach promotes sustainability, in construction leading to conservation and embodied energy. These eco-friendly practices play a role in lessening the negative impact of construction projects on the environment.

3.3.2.3 *Energy efficiency* Additionally, 3D printing showcases energy efficiency and flexibility. P1, P3, and P5 state that projects can be executed without electricity, there is an instance where they resorted to using a small generator. This is in agreement with the study by Aleksandra (2018) highlighting the decreased reliance on energy sources of 3D Printing technologies. This adaptability allows for construction in remote or off-grid areas facilitating infrastructure development in regions with access to electricity. The lower energy demand for 3D printing supports construction in places where conventional projects might encounter delays due to energy limitations which could be the case for rural areas in Malawi.

3.3.3 *Economic impacts*

3.3.3.1 *Construction cost reduction* Moreover, 3D printing technology has the potential to bring about cost savings in construction. A detailed cost-benefit analysis of the 40 m^2 3D printed house in Lilongwe revealed a cost reduction of 2.13% compared to methods. P1 highlighted that this technology has the potential to save more costs in the future. This finding is consistent with research by Abdalla *et al.* (2021) indicating that 3D printing could lower project expenses by, up to 35% when compared to masonry construction methods. The cost savings come from lower Labor expenses, quicker construction timelines, and efficient use of materials (Mendes 2017). These reduced construction expenses could greatly benefit

Malawi's struggling economy by reducing the costs of building projects. Traditional methods often require more time and manpower whereas 3D printing offers a solution to enhance the affordability and accessibility of construction projects.

3.3.3.2 *High initial costs* Although 3D printing technology brings cost advantages to construction it also involves substantial upfront investments for importing 3D printers and hiring foreign consultants for installation and training. P2, and P4 underscored that the COBOD printer used in these initiatives cost up to $500,000. This aligns with research by Kronast (2021) indicating that high initial expenditures pose obstacles to the adoption of 3D printing. P3 highlighted that the organization now has its own printer, they will not have to spend more on printer logistics from Spain. This is inlign with Aghimieng *et al.* (2021) which proposed that organizations can tackle these cost challenges by investing in owning printers which will reduce lifecycle costs.

3.3.3.3 *Promoting local markets* Initially, 3D printing initiatives in Malawi relied on imported materials from Spain, however they later shifted to using ink formulations sourced locally resulting in a cost decrease from $8,000 to $250 per ton (P4,P6). These findings align with Leal *et al.* (2020) indicating that utilizing local materials not only cuts importing expenses but also boosts the economy by creating demand for local resources, creating employment for local people. This integration contributes to the growth of local markets. Decreasing reliance, on imported materials can strengthen industries, improve supply chains, and lead to robust and cost-efficient construction practices.

3.3.3.4 *Resilient infrastructure* Structures created using 3D printing, in Malawi have demonstrated durability boasting a strength of 21 MPa, which far surpasses the standard of 3 MPa for concrete blocks (P3, P4, P7). This sturdiness enhances the ability of infrastructure to withstand weather conditions thereby decreasing the frequency of repairs and maintenance. The research findings are align with the study by Mighty Buildings, (2021) which underscored that additive manufacturing presents solutions for creating resilient construction practices. These structures can endure conditions. Contribute to a more dependable infrastructure system. This resilience not only brings advantages by reducing costs related to disaster recovery and infrastructure damage but also fosters long-term stability and sustainability, within Malawi's construction industry.

4 CONCLUSIONS

The construction sector in Malawi, which is a crucial component of the country's economy, is afflicted by major challenges. The findings of this study showcased the revolutionary capacity of 3D printing from three local projects, the House in Lilongwe, the School in Salima, and the Early Childhood Development Centre in Phalombe. The use of 3D Printing technology in these projects showed many beneficial effects on society, economy, and the environment including by reduction of building schedules, minimized energy and material wastage, and lowered carbon emissions among other benefits. This technology has the capacity to significantly contribute to enhancing infrastructure resilience, addressing the scarcity of schools and residences, and aiding in post-disaster recovery efforts in the country. Nevertheless, challenges such as high expenses and dependence on imported resources need the implementation of strategic remedies. Recommendations include the promotion of the manufacturing of 3D printing materials, enhancement of skills training, and the cultivation of collaboration among stakeholders, government bodies, and policymakers. This research specifically examined the immediate effects of 3D Printing. Future research endeavors might investigate the extended resilience and expandability of 3D printed constructions, as well as their socio-economic impacts on local communities.

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Theme 8: Equity, social justice & empowerment

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Assessing the levels of compliance of building standards for persons with disabilities

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ABSTRACT: In Zambia, the creation of accessible public spaces is vital for the integration of persons with disabilities (PWD). The project aimed to assess the levels of compliance with building standards for PWD in the construction industry in Zambia. Existing standards were examined. Additionally, a case study of the new University of Zambia (UNZA) hostel buildings was done to check the levels of compliance using an adapted checklist focusing on mobility and the visually impaired. 104 parameters were checked for compliance with the ISO 21542_2011 standard. The levels of compliance with the new UNZA student hostel design were less than 50 percent. Though Zambia does not have recommended or mandatory compliance levels, achieving a 90 percent or higher compliance rate represents a step to ensure efforts and strategic improvements in future building design projects.

Keywords: accessibility, compliance, persons with disabilities, and international standards

1 INTRODUCTION

Accessibility of buildings is defined as a way that enables individuals to access and use the environment safely and comfortably (Chahine 2013). It ensures that people have equal opportunities to participate in social, economic, and cultural activities that may take place in that environment. Over the years, the concept of accessibility has gained increasing importance as societies continue to face challenges that develop with an aging population and an increasing number of people living with disabilities.

Persons with disabilities (PWD) face marginalization globally, reflected in the inaccessibility of public buildings in Zambia, posing significant barriers, especially for those with mobility and visual impairments, hindering their access to education, employment, and healthcare services (Chilufya 2013). The lack of accessibility infringes upon their rights to dignity and equality. This issue persists due to buildings being constructed without considering PWD needs and non-compliance with accessibility standards like the Persons with Disabilities Act of 2012.

1.1 *Research aim/question*

The research aims to assess the levels of compliance with building standards for PWD in the construction industry in Zambia by catering to the following specific objective:

- To determine the levels of compliance with INTERNATIONAL STANDARD ISO 21542 First Edition 2011-12-15 of the student hostel buildings being built at UNZA. The research question is, are the standards for building construction for people with disabilities followed in the process of the design and construction of buildings?

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1.2 *Scope of work*

A case study was conducted on the new UNZA Student Hostels. The project involves the construction of 26 hostel buildings with similar designs but different numbers of stories. The study analyzed the level of compliance with International Standard ISO 21542, First Edition, 2011-12-15. The assessment specifically targeted the areas shown in the table below to address the pressing need for improved accessibility in public buildings.

Table 1. Focus areas based on disability

Types Disability Area	Focus
For Mobility Impairments	• Designated accessible parking • Entryways and exits • Movement Circulation • Ramps • Lifts (Elevators) • Common rooms • Sanitary Rooms
For Visual Impairments	• Signage, and other communication Features
For Both Mobility and Visual Impairments combined	• Designated accessible parking • Entryways and exits • Stairs • Handrails • Signage, and other communication features

Source 1: Author (2023).

2 LITERATURE REVIEW

Accessibility in public buildings is a crucial aspect of inclusive urban development, ensuring that persons with disabilities (PWD) can participate fully in society. Various studies have highlighted the challenges and importance of adherence to building standards for accessibility

According to the Centers for Disease Control and Prevention (CDC 2020), a disability refers to any condition of the body or mind that can make it more challenging for individuals to perform certain activities (activity limitation) and interact with the world around them (participation restrictions). Disability categorizes disabilities into 3 dimensions (WHO 2011):

(i) impairment in a person's body structure or function, or mental functioning–an absence of or significant difference in a person's body structure or function; examples of impairments include loss of a limb, loss of vision, or memory loss.
(ii) activity limitation, such as difficulty seeing, hearing, walking, or problem-solving.
(iii) participation restrictions in normal daily activities, such as working, engaging in social and recreational activities, and obtaining health care and preventive services.

2.1 *Levels of disabilities: A case study of Zambia*

The Government of the Republic of Zambia (GRZ 2022) estimates from its national census that 2.7 percent of the national population, equivalent to 256,690 individuals, are persons with disabilities (PWD). Among them, 52.8 percent are male, and 47.2 percent are female. The distribution between urban and rural areas indicates that 26 percent reside in urban areas, while 74 percent live in rural areas. The most common disabilities reported are mobility impairments (38.8 percent) and visual impairments (30.2 percent). Thus, the study focused on mobility and visual impairments, as they are the most prevalent in Zambia.

Furthermore, a study conducted by the World Health Organization (WHO 2006), referenced in the 2011 World Report, aimed to understand the living conditions of individuals with disabilities in Zambia and confirmed previous findings, highlighting mobility impairment as the most prevalent disability in Zambia, followed by visual impairment.

2.2 *Accessibility laws and policies in Zambia for PWD*

Zambia is committed to enabling persons with disabilities (PWD) to live independently and participate fully in all aspects of life, as a signatory to the United Nations Convention on the Rights of Persons with Disabilities. The Persons with Disabilities Act No. 33 of 1996 prohibits discrimination against PWD and establishes mechanisms for their empowerment. The National Policy on Disabilities (NPD) was formulated in 2012 to provide a comprehensive framework for addressing disability issues in the country. One key aspect of the NPD is Section 6.9 on Disability and Accessibility, which outlines specific objectives to enhance accessibility for PWD. These measures are crucial for promoting inclusion and safeguarding the rights of PWD in Zambian society.

2.3 *Standards for accessibility of buildings by PWD*

The importance of standards for construction, which provide guidelines for building designs that are safe, efficient, and sustainable. The ISO 21542_2011 standard defines how the built environment should be designed to enable PWD to approach, enter, use, egress, and evacuate a building independently, equitably, and with dignity. It uses universal design, which is an approach that aims to create products, environments, and systems that are usable by all people to the greatest extent possible.

ISO 21542_2011 is a globally recognized standard that countries use as a reference for creating or revising their accessibility legislation. It has led to the creation of training programs and resources, making it easier for experts from different countries to work together on accessibility projects. Several success stories, including the Sainsbury Center for Visual Arts in the UK and Singapore's accessible city, demonstrate the positive impact of ISO 21542. Compliance with these standards is vital for creating environments that are inclusive and supportive of PWD.

2.4 *Compliance issues in different contexts*

Despite the existence of these standards, compliance remains a significant challenge. Studies have shown that many public buildings do not fully adhere to accessibility guidelines. The accessibility conditions of public buildings and found widespread inadequacies, which pose significant barriers to PWD (Andrade and Ely 2012). Similarly, the lack of wheelchair accessibility in public buildings in Ibadan, Nigeria, highlighting the need for more rigorous enforcement of accessibility standards (Hamzat and Dada 2005).

In Zambia, Chilufya (2013) identified several barriers that PWD face in accessing public buildings, including inadequate ramps, lack of tactile signage, and poorly designed restrooms. These findings showed that many public buildings in Zambia fail to comply with the Persons with Disabilities Act of 2012, which mandates accessibility in public buildings.

2.5 *Impact of non-compliance*

Non-compliance with accessibility standards has significant implications for PWD. (Eide *et al.* 2023) discusses the relationship between disability and poverty, noting that inaccessible buildings exacerbate economic disparities by limiting PWD's access to education, employment, and essential services. This underscores the broader societal impact of accessibility issues and highlights the importance of inclusive design in reducing barriers for PWD.

2.6 *Efforts towards improvement*

Efforts to improve accessibility in public buildings have been documented in various studies. Accessible environments are crucial for the social inclusion of PWD, and effective policies and practices can significantly enhance their quality of life (Chahine 2013). The Institute for Human-Centered Design (2010) provides an ADA Checklist for Existing Facilities, which is used primarily in the United States to assess and ensure compliance with the Americans with Disabilities Act (ADA). This checklist covers various aspects of accessibility, including entrances, routes, and amenities, and serves as a valuable tool for identifying and addressing accessibility issues in existing buildings.

2.7 *Research gaps and future directions*

While significant progress has been made, there are still gaps in the research that need to be addressed. Specifically, there is a lack of comprehensive assessments of new public buildings, especially in higher education institutions in Zambia, to determine their compliance with international accessibility standards such as ISO 21542:2011. Most existing studies focus on older buildings or public facilities in urban areas, leaving a gap in understanding the accessibility of newer constructions in educational settings.

2.8 *Roles of the construction industry in compliance with standards*

In the construction industry, adherence to building codes, standards, and regulations is crucial. Clients initiate projects and collaborate with engineers to ensure accessibility for persons with disabilities (PWD). Consultants manage projects to meet accessibility standards, while contractors implement measures and advise on compliance during construction, all aimed at creating inclusive environments for PWD.

3 METHODOLOGY

The research aimed to evaluate the accessibility and usability of the new hostel building at UNZA using ISO 21542 as the benchmark. The study period was from February to October 2023, and a cross-sectional design was employed. A cross-sectional design was done to assess the building's accessibility at a specific point in time. This design is efficient and effective for capturing a snapshot of the building's compliance with accessibility standards. Data collection involved primary observations and secondary sources such as architectural drawings and literature reviews. Necessary measurements of the routes, entrances, heights, or depths were measured using appropriate measuring equipment (e.g., a tape measure) and recorded. All entry points and connecting routes of the building were taken note of, as well as some interior components of the building in relation to accessibility. However, due to the incompleteness of the buildings under observation, not all necessary measurements could be taken directly from the site. In such cases, reference was made to the architectural drawings of the buildings. However, if the necessary information was not found in the documentation, it was then labeled and checked as inconclusive.

A checklist, adapted from the ADA checklist for existing buildings, that was based on ISO 21542 requirements served as the primary tool for assessing accessibility. The checklist was adapted from the ADA checklist for existing buildings, primarily used in the United States as an instrument to check building accessibility for persons with disabilities.

The project aimed to provide a strong evaluation of the hostel building's accessibility while contributing to the enhancement of inclusive infrastructure in Zambia's construction sector. Table 2 indicates a brief description of the methods used in this project.

Table 2. Brief methodology.

OBJECTIVE	METHODOLOGY
To determine the levels of compliance with INTERNATIONAL STANDARD ISO21542 First Edition 2011-12-15 of the new hostel buildings being built at UNZA	A desk study of the documents related to the project, such as the bill of quantities, and drawings. Site visits and inspections of the new hostel buildings being built at UNZA.

Source 2: Author (2023).

The reliability of this methodology is grounded in several aspects. To start with, combining primary observations with secondary sources ensures a thorough evaluation. Direct measurements provide precise, real-world data, while architectural drawings fill in gaps, particularly for incomplete sections of the building. Moreover, using an adapted ADA checklist based on ISO 21542 guarantees that the assessment covers all necessary aspects of accessibility systematically. This standardized approach minimizes subjectivity and enhances the reproducibility of the study. Furthermore, cross-referencing the observed data with architectural plans validates the findings, ensuring accuracy and consistency. This dual-check approach reduces errors and enhances the credibility of the results. Additionally, the methodology's flexibility in handling incomplete buildings by referring to architectural drawings ensures continuous data collection. Clearly labeling inconclusive data maintains transparency, highlighting areas needing further investigation. Likewise, by adhering to internationally recognized standards (ISO 21542 and ADA), the methodology ensures that the evaluation is relevant and can be compared with similar studies globally. This alignment provides a strong framework that is widely accepted and trusted in the field of accessibility research.

4 RESULTS AND FINDINGS

Compliance information was gathered following ISO 21542:2011 using an adapted checklist. The data were collected on accessibility for the mobility and visually impaired. The compliance section highlights the areas where the hostel design excels, the non-compliance section highlights the areas that did not adhere to the standards, and the inconclusive section clarifies certain areas that could not be checked. The compliance levels for the new UNZA hostel building design in comparison to the standards using the adapted checklist are summarized in the following tables.

Table 3. Summary of compliance for mobility impairments.

Compliant	Non-Compliant	Inconclusive	Total
19.0	37.0	5.0	61
Compliant (%)	Non-Compliant (%)	Inconclusive (%)	
31.1	60.7	8.2	

Source 3: Author (2023).

Table 4. Summary of compliance for visual impairments.

Compliant	Non-Compliant	Inconclusive	Total
0.0	6.0	0.0	6
Compliant (%)	Non-Compliant (%)	Inconclusive (%)	
0.0	100.0	0.0	

Source 4: Author (2023).

Table 5. Summary of compliance for both mobility and visual impairments.

Compliant	Non-Compliant	Inconclusive	Total
28.0	0.0	9.0	37
Compliant (%)	Non-Compliant (%)	Inconclusive (%)	
75.7	0.0	24.3	

Source 5: Author (2023).

Table 6. Overall summary of compliance.

Compliant	Non-Compliant	Inconclusive	Total
47	43	14	104
Compliant (%)	Non-Compliant (%)	Inconclusive (%)	
45.2	41.3	13.5	

Source 6: Author (2023).

The results of the compliance assessment are depicted in Figure 1, which shows that the levels of compliance with the new UNZA Student Hostel design are less than 50%.

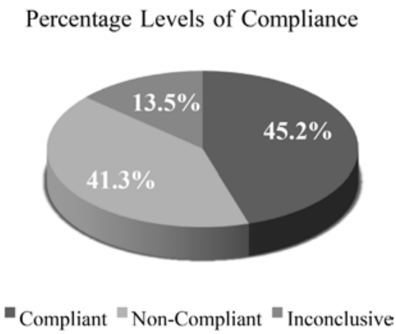

Figure 1. Percentage levels of compliance pie chart. Source 7: Author (2023).

It is apparent from the information gathered that 47 parameters, which is 45.2% of the building design, comply with the standards. However, a sizable 43 parameters, or 41.3%, fail to meet the standards, showing large areas of non-compliance. Furthermore, 14 parameters, which are 13.5% of the design parameters, are inconclusive and require further investigation.

5 DISCUSSIONS

5.1 *Accessibility for mobility-impaired persons*

The evaluation of parameters concerning mobility-impaired individuals reveals critical gaps in the building design. The results found that while 31.1% comply with standards, a substantial 60.7% demonstrate non-compliance across 37 parameters. An additional 8.2% of the parameters remain inconclusive. Importantly, these results are consistent with findings from other research studies, reinforcing the fact that these challenges are not isolated incidents but part of a broader issue. (Yarfi *et al.* 2017) Physically challenged persons in Kumasi who use wheelchairs to ambulate can only gain access to 40.5% of the public buildings that house facilities that provide services for health, education, sports and recreation, religious, and banking needs. (Hamzat and Dada 2005) Only 20% of public buildings assessed were accessible to wheelchair users in Ibadan. The analysis revealed that the most inaccessible parameters for the mobility impaired were: designated accessible parking, ramps, lifts (elevators), and sanitary rooms. This is different from the results found (Moyo and Munyonga 2001) in Harare, Zimbabwe, which found that of the various items surveyed, elevators recorded the highest average accessibility (83% compliance), while parking areas recorded the lowest average of 18%. The compliance score of ramps was 39%, while entrances were 71% compliant. Wheelchair accessibility to toilets was 51%.

5.2 *Accessibility for visually impaired persons*

The evaluation of parameters for mobility-impaired individuals revealed critical gaps in building design. The study found that all parameters were non-compliant with standards, indicating a significant lack of compliance in all areas reviewed. This highlights the urgent need for comprehensive improvements and redesigns to meet requirements and promote an inclusive environment for all. These results are similar to those found that showed that for the visually impaired, access is limited by a lack of adequate and reachable communication features (Andrade and Ely 2012). Moreover, accessibility barriers (such as a lack of signage) for the visually impaired create difficulty in accessing basic amenities such as canteens, toilets, etc (Seigal and Narayan 2014).

5.3 *Accessibility for both mobility and visually impaired persons*

In evaluating accessibility for both mobility and visually impaired individuals, it is noteworthy that there was a commendable level of compliance, reaching 75.7%. This signifies a significant achievement in ensuring spaces are accessible and accommodating for individuals with diverse needs. However, the remaining results were inconclusive, indicating areas that require further examination and improvements to guarantee comprehensive accessibility throughout the premises.

5.4 *Overall accessibility*

The study presents a mixed perspective on building design compliance. While 45.2% of the building design complies with established standards, 41.3% of the design falls short of expected standards. Additionally, 13.5% of the design parameters are inconclusive. The findings highlight the need for improvement and focused interventions in building design processes to ensure safety, accessibility, and inclusivity. Though there is no universally agreed-upon percentage for compliance, achieving a 90% or higher compliance rate represents a significant step towards promoting an inclusive environment, equal opportunities, and upholding the principles of accessibility and universal design.

5.5 *Implementation challenges and best practices*

Despite the significant contributions that ISO 21542 can make in terms of accessibility, there may be difficulties in putting its guidelines into practice.

a) Awareness and Education: Many professionals in the construction industry may not be fully aware of the standard's requirements or the significance of accessibility.
b) Cost Factors: Integrating accessibility elements might occasionally be seen as expensive, which may deter compliance.
c) Retrofitting Existing Buildings: Retrofitting older buildings to fulfill ISO 21542 requirements can be difficult and expensive.

5.6 *ADA checklist for existing buildings Vs. adapted checklist*

The text discusses two checklists for evaluating the accessibility of buildings: the ADA Checklist for Existing Buildings and an adapted version. Both checklists simplify the evaluation process by condensing complex accessibility standards into straightforward questions. They enhance usability by streamlining requirements into yes-or-no questions. However, the adapted checklist's structural organization is tailored to specific disabilities, accommodating diverse needs. The ADA checklist aligns with the 2010 ADA Standards for Accessible Design in the US, while the adapted checklist is based on a global standard that emphasizes usability and accessibility of the built environment.

6 CONCLUSION AND RECOMMENDATIONS

6.1 *Conclusion*

In conclusion, it is evident from the study that Zambia urgently requires a dedicated national standard for ensuring accessibility in buildings for individuals with disabilities. Despite the utilization of ISO 21542:2011 as a guiding principle, the compliance levels of the new UNZA hostel buildings fall significantly short, with only 45.2% adherence to design parameters. This stark reality underscores the necessity for targeted efforts and strategic improvements to guarantee the safety and accessibility of such infrastructure.

However, the study's approach could benefit from further refinement to ensure the creation of truly universally accessible buildings. The equal weighting of parameters presents a notable limitation, prompting the exploration of nuanced weighting for more accurate assessments. Furthermore, the decision to restrict the scope solely to hostel buildings may overlook crucial accessibility challenges in other high-traffic public spaces, highlighting the importance of a broader investigation into these issues.

The practical implications of these findings are clear. It is imperative for policymakers, architects, and builders to prioritize the establishment and enforcement of accessibility standards in building design and construction. By addressing these deficiencies, we not only promote inclusivity but also uphold our international commitments, ultimately improving the quality of life for individuals with disabilities in Zambia.

6.2 *Recommendations*

Investing in accessibility is crucial for construction project owners and employers. It requires prioritizing accessibility throughout the planning and execution of projects and consulting with accessibility experts for compliance and best practices. This ensures inclusive environments that cater to the needs of all individuals. Consultants and contractors involved in construction projects need staff training to enhance their understanding of accessibility requirements. Ongoing education and collaboration with accessibility experts can help them effectively incorporate accessibility features into their designs and construction practices.

Disability advocacy organizations can promote accessibility and inclusive design practices in the construction industry through educational initiatives and policy recommendations. By advocating for accessibility, they can foster a more inclusive built environment. Construction projects should adhere to accessibility standards and undergo routine inspections by regulatory authorities. Standardized compliance assessments and pre-commissioning assessments can ensure that accessibility features are effectively incorporated into projects before use.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Exploring community participation in sustainable infrastructure development: Lessons from Hlalani Kuhle, Bulawayo, Zimbabwe

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ABSTRACT: The study gives insight on community participation in sustainable infrastructure development in Hlalani Kuhle Community in Cowdray Park, Bulawayo, Zimbabwe. It sought to ascertain whether communities are included in development of livable communities in the age of sustainability and overcome a plethora of difficulties through sustainable infrastructure development. The study utilised the qualitative research approach. The study revealed that community participation was largely discouraged by a lot of factors, such as politics, lack of knowledge, expectations, and personal responsibilities. Thus, council social media stakeholder engagement is the only current method of enhancing community participation. As such, there is a need for the Cowdray Park community to form associations that represent them as a whole and are free from political influence. Furthermore, the Bulawayo City Council should seek funding from donors and private investors to facilitate sustainable infrastructure development in Cowdray Park, as well as to implement in situ upgrading.

Keywords: Community participation, livable communities, sustainable infrastructure development, stakeholder engagement, in-situ upgrading

1 INTRODUCTION

Over the past few decades, there has been an increasing global concern for sustainable infrastructure development. The notion of sustainable infrastructure is based on the idea of constructing more effective and environmentally friendly buildings. Sustainable infrastructure also entails other amenities that suit the demands of communities while safeguarding the ability of future generations to satisfy their own needs (Admas 2021). Consequently, community engagement has become a critical component in encouraging sustainable infrastructure development.

The 2015 UN General Assembly adopted the Sustainable Development Goals (SDGs) as global instruments for sustainable development. They promise to ‘transform our world’ and create a nearly comprehensive framework for sustainable development until 2030 (Henfrey *et al.* 2023). As such, researchers have called for the goals to focus on various aspects of inclusion, including the need to recognise and encourage base actors and procedures that can contribute to the ‘transformative innovation’ that any serious attempt at global sustainability must foreground (Kowe *et al.* 2022).

The implementation of the SDGs has been mainly led by national governments, and discussions on how to accomplish them tend to take a narrow perspective of non-state players, such as societies at large and organisations representing civil society, as a diverse

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collective group of participants whose involvement is needed only to build trustworthiness for government-led actions (Henfrey *et al.* 2023). This concentration of SDG creation and delivery raises special issues concerning their local-level adoption (Bice *et al.* 2019). Generalised techniques for either deployment or monitoring are unlikely to match various local situations and needs.

The study examines the level of community involvement in the design, implementation, and maintenance of sustainable infrastructure, such as educational facilities, medical centres, transportation networks, and water distribution systems. The study also identified potential obstacles and impediments that restricted community participation in sustainable infrastructure development and made recommendations on how they could be handled.

According to recent census data from ZIMSTAT 2022, Zimbabwe's population has grown by 16.2% in the last decade (Kowe *et al.* 2022). The country now has a total population of 15.1 million. Notably, this increase is concentrated in major cities like Harare and Bulawayo, contributing to the overall growth of the urban population. From 2012 to 2022, the urban population has risen from 33% to 39% of the total population (Kowe *et al.* 2022). This indicates that the need for cities to house people and provide them with basic infrastructure for support is growing. The Transitional Stabilization Plan (TSP) was a short-term economic blueprint implemented by the government of Zimbabwe from 2018 to 2020. It served as a precursor to the National Development Strategy (NDS 1), which outlined Zimbabwe's long-term development agenda (Chitongo 2021). The National Development Strategy 1 (NDS 1) considers housing accommodation as one of the key components necessary for the country's progress.

The economic crisis in Zimbabwe has hampered the government's ability to create low-cost housing, forcing them to recognise the involvement of third parties (Chitongo 2021). Since Cowdray Park, Hlalani Kuhle, a high-density suburb, was created to reduce Bulawayo's slums, it follows suit. People were transferred to this suburb from the slums that the government demolished in 2005 under a mission known as Operation Muramba Tsvina (Operation Restore Order) (Potts and Haward 2007). People were also forced into a formal slum, which was housing stands without water, sewers, or roads. The government promised basic utilities, while end users were expected to fund housing unit development (Potts and Haward 2007). When the official commitment failed to materialise, the people, as the end recipients, had to come up with inventive methods to ensure that they had the fundamental infrastructure they required.

Ultimately, this research project seeks to make a substantial contribution to the expanding body of information on sustainable development of infrastructure. It also seeks to further enrich the existing conversation on the necessity of community involvement in promoting environmentally friendly growth. Infrastructure development has a key role in determining the social, economic, and ecological aspects of an entire neighbourhood or society (Choguill and Choguill 2014). The research will delve into various case studies and analyse the successful incorporation of community participation in sustainable development. By identifying best practices and lessons learned, this study intends to provide valuable insights and practical recommendations for policymakers, practitioners, and community leaders. This research will not only expand our understanding of sustainable infrastructure developers but also emphasise the significance of community participation in achieving long-term sustainable and inclusive development.

2 APPROACH

In 2005, the government of Zimbabwe embarked on a huge clean-up campaign that saw the demolition of illegal structures in urban centers. The project saw the demolition of all unauthorised structures that had mushroomed in city centres following housing shortages, massive work retrenchments, and the closure of industry (Potts and Haward 2007). Against this background, the government launched the controversial cleanup campaign code-named Operation Murambatsvina/Restore Order to rid the country of slums and other illegal structures and related antisocial activities. This was followed by a national reconstruction exercise code-named Operation Garikai/Hlalani Kuhle, designed to re-house those made homeless as a result of Operation Murambatsvina (Kaseke and Dhemba 2006).

From the impact and implications of Operations Murambatsvina and Garikai, it is evident that the housing problem in Zimbabwe is complex and requires interventions that go beyond these seemingly piecemeal solutions (Mufema 2006). In spite of the good intentions of the government, there was a huge outcry from citizens and residents. The communities felt the government had mistreated them, especially because there was little consultation and involvement with stakeholders in the communities. Drawing insights from this experience, this study is motivated to investigate community involvement, or lack thereof, in government-implemented projects or programmes since it is feared that a lack of involvement could negatively impact the environment, economy, and success of projects. However, this investigation intends to assess the extent of involvement by communities in sustainable infrastructure development in Cowdray Park, Hlalani Kuhle high-density residential development area, Bulawayo, Zimbabwe, with the goal of identifying the barriers and opportunities that hinder or foster community participation in the process.

The aim of this study is to explore Community participation in sustainable infrastructure development:

The specific objectives are:

- To ascertain the key obstacles that limit community participation in sustainable infrastructure development in Hlalani Kuhle high-density development.
- To determine the Roles of community participation in sustainable infrastructure development in Hlalani Kuhle high-density development.
- To evaluate the extent of community participation of sustainable infrastructure development in Hlalani Kuhle high-density development.
- To identify strategies and recommendations that can improve community participation in sustainable infrastructure development in Cowdray Park.

Hlalani Kuhle is a semi-formal residential area located within Cowdray Park. It is characterised by settlements that were done in a planned manner but without the requisite infrastructure that is common within fully developed residential areas. In the Hlalani Kuhle residential area located in Cowdray Park, Bulawayo, Zimbabwe, the study focuses on the lack of sewer and water reticulation in households. Additionally, it examines the absence of electricity and the substandard condition of roads, which have not been paved and remain at a bush-clearing level.

The analysis focused on the Hlalani Kuhle community due to the special characteristics, challenges, or opportunities that make it particularly ideal for examining participation in sustainable infrastructure development in the setting of Bulawayo, Zimbabwe. The project intends to evaluate community participation in sustainable infrastructure construction. Therefore, the theoretical scope may include concepts from fields such as community development, sustainable development, participatory development, urban planning, and governance, among others. The study area encompassed the actual geographical limits of this community. The project investigated the degree of community participation in sustainable infrastructure development. It studied the engagement of community members, local organisations, and stakeholders in multiple initiatives connected to infrastructure development within the Hlalani Kuhle neighbourhood.

3 THEORETICAL FRAMEWORK

Public participation facilitates the dissemination of knowledge and increases public awareness of the initiatives of city governments (Masiya *et al.* 2019). Therefore, the involvement of the public support's citizen-focused provision of services enhances municipal reputation among the population. The theoretical component related to public participation is emphasised in Arnstein's 'ladder of civic participation'. Arnstein's theory concentrates on the importance of the public's involvement and is composed of a total of eight rungs, using two levels of absenteeism (manipulation as well as therapy), three types of counterfeiting (informing, advice, as well as placation), and three tiers of citizen power (partnership, assigned authority, and citizen control) (Chirisa *et al.* 2024; Xavier 2021). As a theoretical framework, this research will utilise Arnstein's 'ladder of citizen participation to identify and evaluate the various levels of community participation in sustainable infrastructure development in Cowdray Park and the Hlalani Kuhle high-density residential development area. Arnstein's ladder is illustrated in Figure 1.

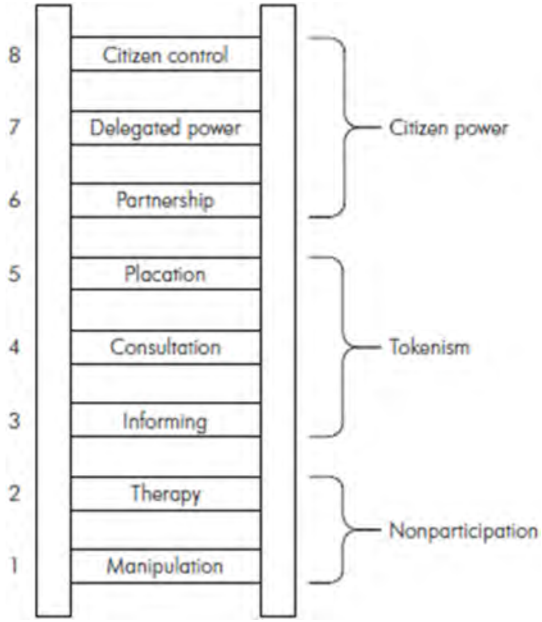

Figure 1. The ladder of citizen participation. Source: (Masiya *et al.* 2019).

At the manipulation level, the process of decision-making is manipulative and is imposed on citizens to accomplish an outcome that localities have already decided on, while therapy can be considered mere publicity exercises by localities to secure people's support (Musakwa and Moyo 2020). Therefore, the informing level points out a one-way flow of knowledge, and there are no avenues for suggestions, whereas the consultation level is distinguished by procedures such as attitude surveys, community meetings, and public requests but remains a weak form of participation and is often a separate dressing exercise (Masiya *et al.* 2019). Thus, the placation level is where the power holders retain the right to assess the legitimacy or viability of advice from participants, even though they allow, for example, the co-option of hand-picked 'worthies' onto committees.

The first five levels represent what Arnstein called "tokenism," where people are able to hear and be heard but have no power to have their views regarded by the powerful or by decision-makers. Therefore, at these levels of involvement, there is no guarantee that the status quo of policies, laws, or initiatives will be changed (Xavier 2021). Participation that is restricted to these five levels does not contribute to any change in the status quo and, hence, would not bring about significant involvement. As such, the powerless can accomplish some sort of advice (placation), but the authority bearers remain the ones who determine what can be performed and how.

Therefore, owing to the increasing need to achieve Agenda 2030, notably regarding Sustainable Development Goal 11, which is designated for sustainable cities and communities, the achievement of these solid Sustainable Development Goals flows down to the communities in the form of areas under the oversight of local governments, such as Cowdray Park. Therefore, due to the presumptions of Arnstein's 'ladder of citizen participation, which is connected alongside participation in various manners, it is the most ideal theory for comprehending the involvement of communities in sustainable infrastructure development in Cowdray Park and Hlalani Kuhle's high-density residential development area.

4 FINDINGS AND DISCUSSIONS

The study comprised four thematic areas that were related to the research question of this study. The first thematic area focused on information on factors that hinder community participation in sustainable infrastructure development, and this thematic area was further fragmented into three subthemes that focused on the factors that discourage community participation, challenges faced during infrastructure development, and ways to increase community involvement. Results revealed that community participation is largely discouraged by factors such as politics, lack of knowledge, expectations, and personal responsibilities. These include lack of funding, poor servicing, dust, and death. It was also exhumed that there is a need for proper structures of community engagement, finances, and education.

The second thematic area focused on enhancing community participation in sustainable infrastructure development, and this thematic area was further fragmented into three subthemes that focused on current methods of enhancing community participation, current challenges facing community participation, and strategies to further enhance community participation. The study found that political campaigns and council social media stakeholder engagement are the only current methods to enhance community participation in Cowdray Park. The current challenges ranged from economic, political, disengagement between stakeholders, poor service delivery, poor leadership, and poverty. The study further established that adoption of GIS, education, creating associations, availing funds, prioritising communication, and seeking donors can further enhance community participation.

The third thematic area focused on the contribution of sustainable infrastructure development to environmental sustainability. This thematic area was further fragmented into three subthemes that focused on understanding the concept of sustainable infrastructure development, ways of implementing sustainable infrastructure development in Cowdray Park, and measures to ensure sustainable infrastructure development contributes to environmental sustainability. The study revealed that sustainable infrastructure was understood as infrastructure that could last longer, be functional, and benefit the community. Furthermore, there are various ways to implement sustainable infrastructure development, such as engagement of stakeholders, in situ upgrading, education, employing community members, and seeking funding. In addition to this, the study found that there is a need for coordinated development, education, partnerships with innovative organisations, using strong materials, enforcement of policy, clean-up campaigns, increasing frequency and vehicles for garbage collection, and ensuring monitoring and evaluation for sustainable infrastructure development to contribute to environmental sustainability.

The fourth thematic area focused on strategies to ensure the sustainability of community-led infrastructure development. The thematic area was further fragmented into three subthemes that focused on previous approaches to community-led infrastructure development, factors that contribute to the sustainability of community-led infrastructure development, and strategies that ensure the sustainability of community-led infrastructure development. The study found that there was some community-led infrastructure development that had been implemented, focusing on housing by organisations and individuals, the purchase of poles and power lines for electricity, and the filling of gullies and potholes on roads. Moreover, factors that contribute to the sustainability of community-led infrastructure include participatory planning, investment, education, and setting proper goals. The study also found that the strategies for ensuring the sustainability of community-led infrastructure development include education, setting up community associations, funding, setting neighbourhood security, using strong materials for infrastructure development, and partnerships with the local authority.

5 CONCLUSION

The study sought to explore community participation in sustainable infrastructure development. The study revealed that community participation was largely discouraged by a lot of factors, such as politics, lack of knowledge, expectations, and personal responsibilities. Thus, council social media stakeholder engagement is the only current method of enhancing community participation. As such, there is a need for the Cowdray Park community to form associations that represent them as a whole and are free from political influence. Furthermore, the Bulawayo City Council should seek funding from donors and private investors to facilitate sustainable infrastructure development in Cowdray Park, as well as to implement in situ upgrading.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Role players' investment challenges on health insurance cover for construction workers in Lafia, Nigeria

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ABSTRACT: This study is an attempt to assess the awareness and implementation of comprehensive health insurance coverage for construction workers in Lafia metropolis, Nigeria. The study adopted quantitative research and a total of 110 questionnaires was purposively distributed via email and hand delivery to the respondents, but only 70 questionnaires were retrieved and found relevant. Thus, 70 respondents include construction professionals, skilled, and unskilled construction workers across the Lafia metropolis, Nigeria. The study findings revealed that there is significant awareness of the potentiality to invest in various health insurance covers for construction workers. There is insufficient investment by the construction role players in health insurance coverage. Thus, these investment challenges would pose significant health and safety challenges to workers when injured on duty. The study concluded that these investment challenges are based on role players' limited awareness and negligence of social and economic benefits for construction workers' covered health insurance.

Keywords: Construction workers, health Insurance cover, investment challenges, Lafia metropolis, Nigeria

1 INTRODUCTION

In many countries, the construction sector continues to be an essential pillar of national development, stimulating economic growth and enabling the expansion of infrastructure (Anugwo 2017). However, due to the nature of their employment, construction workers are exposed to a variety of health and safety risks, which increases their risk of illnesses, injury, and, in extreme cases, death (Okorie and Anugwo 2023). Unfortunately, in the face of these overwhelming obstacles, obtaining practically assessed comprehensive health insurance remains a major challenges for many construction workers. The unstable health conditions and restricted access to healthcare services that construction workers face have been revealed by recent studies. Thus, the study by Johnson *et al.* (2022) have shown how urgent it is to overcome the gaps in health care coverage that currently exist in the construction industry. According to Johnson et al (2022) only a small fraction of construction workers have access to adequate health insurance. Therefore, access to health insurance for construction workers remains a critical issue in the current healthcare landscape in Nigeria. A strong health insurance infrastructure can support a healthier and more productive workforce, which can lead to increased efficiency and overall development in the construction industry. Better health coverage can also contribute to higher job satisfaction and worker retention, which

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can promote stability and growth within the construction labor market (Smith *et al.* 2023). Thus, the implementation of targeted policy interventions, drawing inspiration from successful international models, can potentially mitigate the existing disparities and enhance health insurance accessibility for this crucial workforce in Nigeria. Therefore, this study aimed to investigate the possibilities of either introducing or improving the provision of health insurance for the construction workers in Lafia metropolis in Nigeria. In order to achieve the aim of this study the following objectives were laid out; to investigate the level of awareness and coverage of health insurance for construction workers across Lafia metropolis, and secondly to examine awareness and challenges of implementing coverage of health insurance policies among construction workers in Lafia metropolis.

2 LITERATURE REVIEW

2.1 *Health insurance: The new Nigerian national health insurance Act 2021*

A basic form of insurance that provides essential financial protection for medical costs and healthcare services is health insurance (Smith *et al.* 2023). Its main goal is to protect people and their families from the astronomical expenses related to medical services and treatments. Many medical services, including doctor visits, hospital stays, prescription medication, preventive care, and certain medical procedures, are covered by a standard health insurance plan (Johnson and Lee 2023). To keep their coverage intact, policyholders must pay their insurance provider on a regular basis—either monthly or annually (Brown and Garcia 2023).

In Nigeria, after just 10% of the population was successfully enrolled under the old National Health Insurance Scheme Act of 1999, the Nigerian government approved the new National Health Insurance Act (NHIA) in 2022. With the objective of promoting, regulating, and integrating health insurance programs across the nation, the NHIA has high standards. It aims to create a fund to subsidize health insurance coverage for vulnerable people and the impoverished while making health insurance essential for all Nigerians and legal residents. At the moment, 70% of Nigerians pay for healthcare treatments out of pocket. In 2018, Nigeria Demographic and Health Survey revealed that over 97% of Nigerians do not have any type of health insurance, demonstrating the country's glaring lack of health coverage. Since the NHIA is expected to expand to the vulnerable populations' access to high-quality healthcare, it offers hope to the approximately 83 million Nigerians who are impoverished (Adeleke and Obi 2023). Thus, vulnerable populations (especially construction workers) must be included in the NHIA in order to improve access to healthcare services and encourage the seeking of health. On the other hand, this group's definition and inclusion requirements must be made explicit (Adeleke and Obi 2023).

2.2 *The sustainable development goals (SDGS): Overview on access to high-quality health services*

In order to guarantee that all individuals and communities across the globe have access to high-quality health services, the sustainable development goals (SDGs) highlight the global commitment to achieving universal health coverage (UHC) by 2030 (World Health Organization 2022). Although effective coverage of critical health services and financial protection are commonly used to gauge progress in UHC. It is important to understand that low-quality and hazardous services can still lead to poor health outcomes (Kruk *et al.* 2021). Thus, providing high-quality healthcare services is essential to achieving UHC. A large body of research indicates that poor care depletes human capital and lowers productivity in addition to wasting large amounts of money and posing serious dangers to public health (Wang *et al.* 2021).

2.4 *Health insurance awareness and coverage among construction workers*

Health insurance awareness and coverage among construction workers have been a prominent area of concern in various countries. The construction workers often encounter specific health risks attributed to the nature of their work, underscoring the importance of accessible and comprehensive health insurance (Jones and Brown 2022). Thus, health insurance coverage options for construction workers can vary depending on factors such as the country, employer practices, and government policies. Here are some common types of health insurance coverage that construction workers may have access to.

2.4.1 *Employer-based coverage*

Employer-sponsored health insurance, sometimes referred to as employer based coverage, is essential for many people all over the world to have access to healthcare services (Glied and Levy 2019). Employers are required by law or strongly encouraged to provide health insurance benefits to their staff members in nations with a hybrid healthcare system (Jost 2020). Employer-based coverage is extremely important since it makes healthcare services accessible to employees and their families without placing the entire financial burden on them (Blumberg and Holahan 2021). It forms the backbone of the health insurance landscape in several developed and developing countries (Rosenbaum 2019).

2.4.2 *Government initiatives*

In an effort to improve the general health and wellbeing of construction workers, several healthcare policy measures have attempted to provide them with health insurance coverage. Governments throughout the world have realized how important it is to address the particular health risks that construction workers face and have taken action to give them access to vital healthcare services through specialized insurance plans. Policy analysis and research studies have emphasized the importance of providing health insurance to construction workers. In a research project by Smith *et al.* (2021), it was found that construction workers often face barriers in accessing healthcare services, leading to delayed treatment and increased health complications. By implementing schemes to provide health insurance, governments aim to mitigate these challenges and ensure timely medical attention and preventive care for construction workers.

2.4.3 *Individual health insurance plans and family health coverage*

Individual health insurance policies have emerged as a competitive alternative for self-employed construction workers or those ineligible for employer-sponsored plans in recent years. For employees who do not have access to group insurance plans, these policies provide a way for them to obtain necessary healthcare coverage catered to their individual needs (Patel *et al.* 2022). Individual health insurance coverage offer self-employed construction workers an important way to safeguard their financial security and well-being. Individual health insurance is crucial for self-employed people, according to research by Patel *et al.* (2022), since it protects against unforeseen medical costs and guarantees access to necessary healthcare services. As self-employed workers often do not have the benefit of employer-sponsored plans, individual policies offer them an avenue to secure comprehensive coverage. One noteworthy research conducted by the National Institute for Occupational Safety and Health (NIHS) found that health insurance plans catering to construction workers often encompass comprehensive family coverage options. By allowing the inclusion of family members, these insurance plans go beyond safeguarding the health interests of the workers themselves, but also extend a safety net to their loved ones, guaranteeing equitable access to healthcare services for the entire family unit (Smith *et al.* 2022).

2.5 *Challenges on the implementation of health insurance awareness and coverage among construction workers*

Implementing health insurance awareness and coverage among construction workers is met with various challenges that hinder the successful execution of such programs. These challenges encompass factors that impede the dissemination of information, financial barriers, and the unique circumstances of the construction industry. These include the nomadic work patterns, financial constraints, and occupational hazards prevalent in the construction industry. Recent studies have identified these challenges as significant barriers to ensuring that construction workers have access to adequate health insurance protection (Johnson and Martinez 2021; Smith *et al.* 2020). The unpredictable nature of construction work and fluctuating income streams often dissuade workers from investing in insurance due to perceived affordability issues. Furthermore, the transient nature of employment can lead to frequent changes in health insurance coverage, rendering the process of securing consistent coverage more challenging (Brown *et al.* 2019).

2.5.1 *Limited awareness and education*

In recent times, the lack of sufficient awareness and understanding about health insurance among construction workers has been increasingly recognized as a substantial challenge that hampers the effective implementation of health insurance policies within the construction industry. This issue stems from a variety of factors that converge to create a complex landscape wherein construction workers may not fully comprehend the significance and advantages of having health insurance coverage. A notable portion of construction workers often lacks insight into the intricate workings of insurance mechanisms, the extent of coverage it provides, and the potential role it plays in safeguarding their overall health and well-being. Addressing this challenge necessitates multifaceted approaches that combine targeted educational efforts with accessible and relatable communication strategies. Research findings emphasize the pivotal role of comprehensive and tailored educational campaigns in bridging the knowledge gap among construction workers (Smith *et al.* 2020).

2.5.2 *Transient nature and inconsistent employment patterns of construction work*

The construction industry is renowned for its distinctive employment landscape, which is marked by high mobility and a dynamic pattern of engagement with varying employers. This transient nature of employment within the construction sector presents a complex challenge in establishing and maintaining consistent health insurance coverage for workers. As construction workers frequently transition from one project to another and engage with different employers over time, the continuity of their health insurance coverage becomes vulnerable to disruption, resulting in notable gaps in coverage. These gaps can emerge as workers shift between projects that may have different insurance providers or coverage policies.

3 RESEARCH METHODOLOGY

3.1 *Research design*

This study aimed to explore the enhancement of health insurance access for construction workers in Lafia Local Government Area (LGA), Nasarawa State. The study primarily adopted a quantitative research approach, whilst utilizing questionnaire survey for data collection. The questionnaire's construct where based on a comprehensive review of recent literature, policy documents, and the Nigerian Health Insurance Act, and it was used for primary data collection amongst the construction workers and relevant stakeholders.

3.2 *Study area and study population*

The study was conducted in construction companies located within Lafia Metropolis of Nasarawa State, Nigeria. Lafia is a prominent construction hub in Nasarawa State, providing diverse structures and constructions for people in the region. The selection of this study area is of great significance as it offers a wide representation of Professionals, with varying demographics, Qualifications, and Years of experience. The study involved participants with different roles from various construction firms that carryout various construction projects. A purposive sampling technique was employed to choose participants based on their profession in the construction industry. The total population of interest for this research was 100, which comprises all the professionals including consultants and contractors, however it was only 70 questionnaires that passed for data analysis.

3.3 *Methods of data collection and method of data analysis*

For this study, primary data was collected using a questionnaire as a research instrument. Questionnaires are effective in gathering data from a large sample of subjects who possess independent reading and writing abilities (Kasabov and Benson-Rea 2021). By utilizing a questionnaire, the study ensured homogeneity in the questions and allowed respondents to remain anonymous, facilitating meaningful comparisons. The participants completed the questionnaire as provided and returned it within an agreed time frame. Review of relevant literature from learned journals was also used to collect secondary data. Therefore, the study adopted quantitative research and a total of 110 questionnaires were purposively distributed via email and hand delivery to the respondents, but only 70 questionnaires was retrieved, and found relevant and useful for the study. Thus, 70 respondents were purposefully sought among construction professional (32), skilled (24), and unskilled (14) construction workers across the Lafia metropolis, Nigeria. Quantitative data collected from the survey questionnaire went through analysis using descriptive statistics to ascertain frequencies and percentages, enabling an in-depth examination of the level of access to health insurance for construction workers. The data obtained from the study was analyzed using percentages to determine the distribution of responses for each item, and the mean was calculated to determine the average score for each question. In order to investigate the health insurance awareness and coverage among construction workers in Lafia metropolis, responses from questionnaire survey were evaluated using a five-point Likert Scale with options ranging from Strongly Disagree (1) to Strongly Agree (5). The Mean Item Score (MIS) and ranks were calculated for each option based on the distribution of responses.

4 RESULTS AND DISCUSSIONS

4.1 *Demographic information of the respondents*

Table 1. Profession in the construction industry.

S/N	PROFESSION	FREQUENCY	PERCENTAGE (%)
1	Professional Builder	7	10%
2	Architect	10	14.29%
3	Quantity Surveyor	5	7%
4	Engineer	10	14.29%
5	Foreman	11	16%
6	Iron Bender	5	7%
7	Brick Layer	8	11.42%
8	Labourer	14	20%
TOTAL		70	100

Source: Field data (2023).

Table 1 presents information about various professions within the construction industry. The table displays the frequency and percentage distribution of each profession. The table shows that "Labourer" has the highest frequency at 20%, followed by "Foreman" at 16%. "Architect" and "Engineer" each account for 14.29%. "Professional Builder," "Quantity Surveyor," "Iron Bender," and "Brick Layer" have frequencies ranging from 7% to 11.42%. This data provides insights into the composition of various roles within the construction industry.

Table 2. Organizational type.

S/N	TYPE OF ORGANIZATION	FREQUENCY	PERCENTAGE (%)
1	PRIVATE	36	51%
2	PUBLIC	34	49%
TOTAL		70	100

Source: Field data (2023).

Table 2 provides insights into the types of organizations individuals belong to. "Private" organizations account for the majority at 51%, while "Public" organizations make up the remaining 49%. This indicates that a slightly larger portion of individuals in this group are connected to private organizations compared to those associated with public organizations.

4.2 *Analysis on accessibility to health insurance for construction workers*

Table 3. To investigate health insurance awareness and coverage among construction workers in Lafia Metropolis.

S/N	Health Insurance Awareness and Coverage Among Construction Workers	SA	A	N	DA	SDA	TOTAL	MIS	RANK
		5	4	3	2	1			
1	Employer-Based Coverage	25	29	13	2	1	70	4.07	1
2	Government Initiatives	7	52	10	0	1	70	3.91	2
3	Individual Health Insurance Plans	5	45	18	0	2	70	3.73	3
4	Trade Union or Association Plans	1	52	16	0	1	70	3.74	4
5	Family Coverage	6	33	22	9	0	70	3.51	5
6	Comprehensive Health Coverage	7	54	8	1	0	70	3.96	6
7	Catastrophic Health Insurance	3	49	15	2	1	70	3.73	7
8	Supplemental Health Insurance	5	54	10	1	0	70	3.90	8

Source: Field data (2023).

Table 3 presents an investigation into health insurance awareness and coverage among construction workers in Lafia Metropolis. The responses were evaluated using a five-point Likert Scale with options ranging from Strongly Disagree (1) to Strongly Agree (5). The Mean Item Score (MIS) and ranks were calculated for each option based on the distribution of responses. "Employer-Based Coverage" received the highest MIS of 4.07, making it the top-ranked option. "Government Initiatives" followed with an MIS of 3.91, ranking second. "Individual Health Insurance Plans" obtained an MIS of 3.73, positioning it in third place. "Trade Union or Association Plans" received an MIS of 3.74, securing the fourth rank. "Family Coverage" attained an MIS of 3.51, placing it in fifth position. "Comprehensive

Health Coverage" achieved an MIS of 3.96, ranking sixth. "Catastrophic Health Insurance" received an MIS of 3.73, positioning it seventh. "Supplemental Health Insurance" obtained an MIS of 3.90, securing the eighth rank. The analysis indicates that among the evaluated options, "Employer-Based Coverage" is perceived as the most effective approach for enhancing health insurance awareness and coverage among construction workers in Lafia Metropolis, as it received the highest MIS and rank.

4.3 *Investigation of challenges involved with implementing health insurance for construction workers*

Table 4 below presents an analysis of challenges related to the implementation of health insurance awareness and coverage among construction workers. The Mean Item Score (MIS) and ranks were calculated for each challenge based on the severity of the issue. "Limited Awareness and Education" obtained the highest MIS of 4.63, positioning it as the top-ranked challenge. "Transient Nature and Inconsistent Employment Patterns of Construction Work" followed with an MIS of 4.03, ranking second. "Financial Constraints" received an MIS of 3.99, securing the third rank. "Cultural and Social Factors" achieved an MIS of 3.77, placing it in fourth position. "Pre-existing Health Conditions" attained an MIS of 3.01, positioning it fifth. "Complex Enrollment Processes" received an MIS of 2.61, ranking sixth. "High-Risk Nature of Construction Work" obtained an MIS of 4.19, placing it seventh. "Demographics of the Construction Workforce" achieved an MIS of 3.96, securing the eighth rank. The analysis highlights that among the identified challenges, "Limited Awareness and Education" is perceived as the most significant obstacle to implementing health insurance awareness and coverage among construction workers. It received the highest MIS and rank, suggesting that addressing this challenge could be crucial for successful implementation.

Table 4. To identify the challenges on the implementation of health insurance awareness and coverage among construction workers.

S/N	Challenges on the implementation of Health insurance awareness and coverage among Construction workers	MIS	RANK
1	Limited Awareness and Education	4.63	1
2	Transient Nature and Inconsistent Employment Patterns of Construction Work	4.03	2
3	Financial constraints	3.99	3
4	Cultural and Social factors	3.77	4
5	Pre-existing Health Conditions	3.01	5
6	Complex Enrollment Processes	2.61	6
7	High-Risk Nature of Construction Work	4.19	7
8	Demographics of the Construction Workforce	3.96	8

Source: Field data (2023).

5 CONCLUSION AND RECOMMENDATION

The provided data tables offer comprehensive insights into various aspects of health insurance awareness, coverage, challenges, impacts, and strategies for construction workers in Lafia Metropolis. In Table 3, the data underscores the significance of role players' limited awareness to sufficiently invest in health insurance cover for construction workers and this challenge pose a significant health and safety challenges for construction workers. Thus, the study also concluded that inadequate knowledge on health insurance and its importance by role players, and the transient employment patterns of construction workers, and somewhat financial constraints by construction firms and investors as some of the primary challenges in implementing health insurance coverage for construction workers. The study further reveals that employees' health and well-being, workforce attraction and retention, and safety and workplace productivity are the most impacted factors resulting from health insurance coverage within the construction industry. These findings underscore the need for tailored approaches to enhance health insurance awareness and accessibility among construction workers. The study also recommended that the evaluation of challenges of the transient nature of employment should be primary obstacles as not to cover construction workers rather the social and economic benefits of insurance cover for workers and their family is considered as main objectives.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Unpacking cultural differences in construction project performance: A review

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ABSTRACT: Cultural factors are crucial to project success. Cultural differences cause megaproject failures with conflicts, miscommunication, and misunderstandings. Recognizing this need has spurred a compelling need for comprehensive research in this area. This review comprehensively elucidates the relationship between cultural differences and project performance trends from 2018 to 2023 in developing countries. A bibliometric approach and an analysis of 95 documents retrieved from the Scopus and Web of Science databases were conducted. The findings unveil that cultural management is crucial for the operation of organizations in diverse and dynamic environments in developing countries, as well as the integration of cultural considerations into project management practices. This review provides a basis for scholars to study cultural dynamics and project performance in a globalized world.

Keywords: Cultural Differences, Project Performance, and Cultural Management

1 INTRODUCTION

The success of project-based organizations depends on multiple factors. Notably, cultural factors have gained recognition as significant determinants of project performance (Seiso *et al.* 2023). Culture, defined as the way of life manifested in behavior, habits, attitudes, and beliefs, is crucial in shaping project environments (Sibani M Clifford 2018). It represents the dominant fundamental values and beliefs (Luo *et al.* 2024). Failure to address cultural issues can lead to conflicts and misunderstandings among team members, posing threats to project outcomes (Jones *et al.* 2021). Thus, there is a pressing need for comprehensive research in this domain to build a strong scientific foundation.

While cultural management has been explored for over two centuries, the current surge in interest regarding cultural differences in project performance demands a thorough bibliometric analysis of the published literature (Hofstede 1980; Trompenaars 1997). While previous studies have acknowledged the role of cultural factors in project performance, this paper specifically targets the cultural dynamics within project environments, emphasizing their critical impact on project outcomes (Wu 2022). In this context, understanding the current state of research in this domain using bibliometric analysis can help inform policy discourse and future research directions.

Unlike earlier works that may have provided narrative reviews or limited bibliometric studies, this paper employs a comprehensive bibliometric analysis to evaluate the body of literature. This method enables a systematic assessment of existing research trends and patterns over the past five years, particularly from 2018 to 2023. The paper narrows its focus

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to developing countries, a context that may have unique cultural challenges and dynamics affecting project performance. This geographical specificity addresses a gap in the existing literature that has often focused on more developed regions. By concentrating on literature from the past five years, the study provides an up-to-date overview of the field. This is crucial for understanding contemporary challenges and the evolving nature of cultural impacts on project performance. The findings from the bibliometric analysis are intended to inform policy discourse and guide future research directions. This forward-looking approach ensures that the study not only synthesizes past research but also contributes to the strategic planning of future investigations in this domain.

1.1 *Research method, keyword, and data definition*

The study focused on trends and advancements in cultural differences in project performance research, analyzing publication years, countries, and relationships between top authors, keywords, and sources from 2018 to 2023 and only articles published in English were included (Matsimbe *et al.* 2023). The research conducted a bibliometric analysis to illuminate the evolution and frontiers of the field, following a four-stage review protocol (Donthu *et al.* 2021; Ferlito *et al.* 2022). This protocol involved an extensive search for relevant publications using specific keywords, rigorous application of exclusion criteria to filter these publications, quantitative assessment of scholarly impact and trends through scientometric analysis, and qualitative evaluation via a systematic literature review (Onososen and Musonda 2023). Scopus and Web of Science (WOS) databases were used for comprehensive data collection, and VOSviewer software was employed for its effective presentation of bibliometric information (Liphadzi *et al.* 2022).

Keywords such as "cultural differences," "project performance," and "construction industry" were combined using union keywords like "cultural differences," "project performance," and "construction industry" were combined using a set of union keywords, including terms like cultural OR culture AND differences OR diversity AND project AND performance OR success OR failure OR completion AND construction OR building OR engineering to locate relevant articles. Scopus and WOS were chosen for their capacity to track significant research and provide credible information (Nguyen Van and Nguyen Quoc 2021; O'Grady *et al.* 2021; Pranckutė 2021). Abstracts were reviewed to ensure they met the search criteria (Ferlito *et al.* 2022). VOSviewer and Sciencescape aided in mapping analysis, while Microsoft Excel was used for quality assurance, including duplicate removal.

1.2 *Article search*

Initial searches in Scopus and WOS yielded 985 documents. After applying filters for the specified years and language, 642 and 343 documents remained respectively. Further screening by reviewing abstracts, eliminated 177 leaving 166 for detailed reviewing. Upon removing duplicates of exactly 71 documents, the authors carefully assessed these documents for alignment with the research topic, 95 relevant articles were found eligible for this review.

For the document selection process, the authors conducted a PRISMA search in steps, as depicted in Figure 1.

1.3 *Data analysis*

The following are the criteria used to analyze the portfolios of articles: publication years, countries, and relationships between top authors, keywords, and sources. To build the development of publications per year, the topic area, and corresponding data to the articles, provided by both databases were combined and consolidated. The information attained led to the construction of Figures 2 and 3 below.

2 RESULTS FROM BIBLIOMETRIC ANALYSIS

2.1 *Research evolution*

The following results Figure 2 presents the output per year of the relevant 95 documents reviewed and considered for this study. The graph shows that this study “Cultural Differences to Project Performance” has recently been intensely researched and developed in the construction industry (Liu *et al.* 2020; Yayla *et al.* 2023). This topic is still emerging especially in the effect of multicultural workforce/teams and on construction work productivity (Adriadi *et al.* 2019; Kuoribo *et al.* 2022). However, there is evidence that there is a need for more research to be published in this area.

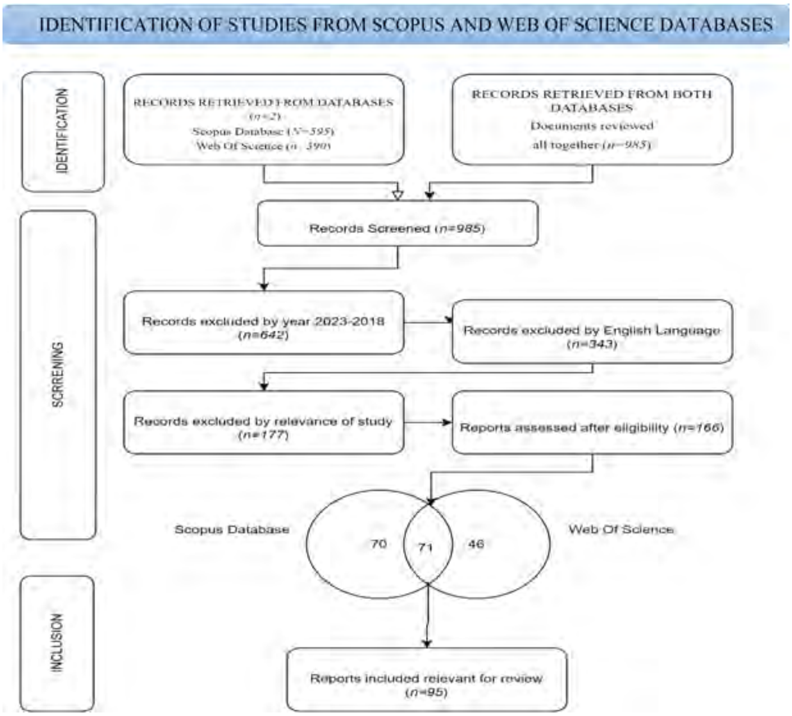

Figure 1. Step-by-step of the document selection process. Source: Made by the authors.

Figure 2. Annual publication trend of Cultural differences on project performance. Source: Made by the authors.

2.2 *Publication per year*

The earliest publication addressing cultural differences in project performance dates back to 2009 (Kivrak and Ross 2009), while Hofstede's research on culture dates back to 1984. The study focused on publications from 2018 to 2023, similar to previous research (Matsimbe *et al.* 2023)(Machado and Martens 2015). The figure does not reveal any consistent pattern in the quantity of papers published over the years. The decline in 2023, with 11 fewer publications, should be considered, bearing in mind that the bibliometric analysis was conducted in November 2023, and the year was not yet complete. The potential for more publications in 2023 exists. For instance, 2022 saw a total of 23 publications. A five-year analysis alone may not sufficiently illustrate fluctuations in publication rates unless combined with data on the overall strength of papers, including their citations. This analysis underscores the increasing awareness and importance of the topic of "cultural differences in project performance" over the years, as evidenced by the significant rise in publication numbers, as depicted in Figure 2.

2.3 *Publication by Country*

Figure 3 shows the publication of papers distributed across countries all over the world. The United States has the highest number of papers published amounting to 22 documents, followed by China with 21 documents, and 14 documents in Australia respectively; whilst Thailand, Bulgaria, and Zambia (of which represent developing countries) have the least publication of documents amounting to 1 document in each country respectively. Developed countries dominate publications giving room for developing countries, however, this bias may hinder representation of research priorities according to regions. There is a lack of knowledge on integrating cultural differences and project performance in developing countries. This may stem from limited funding, institutional support, and technology. As a result, scholars in these regions struggle to publish their research, potentially leading to project failures, such as those experienced in Tanzania due to mishandling cultural diversity.

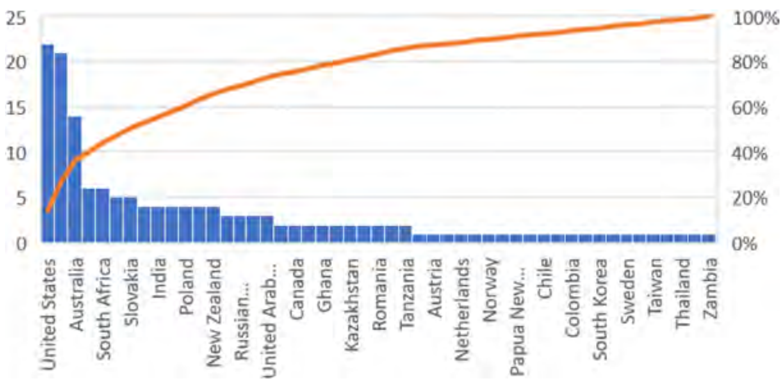

Figure 3. Publication by Country. Source: Made by the authors.

2.4 *Visualization of the documents*

This section provides the visualization of the results from the 95 documents attained from Scopus and Web of Science combined using Vos Viewer. An analysis was done from both Scopus and Web of Science through bibliographic data and further analyzed with Vos-viewer to present the figures respectively.

2.4.1 *Association of top authors, keywords, and publishing journals*

Of 95 documents reviewed, 71 sources were cited and a minimum number of documents of a source was set to 1 to which all 71 sources meet the threshold. To obtain this relationship and prove the above processes, a CVS file was uploaded from Vosviewer to Sciencescape to get the three-field Sankey diagram (Figure 4). The figure depicts the relationship between top authors(left), top keywords(middle) and top journals(right) in this area. The top leading journal "Engineering Construction and Architectural Management" which appears to have published keywords like international construction, simulation, project management, conflict management, project performance, organization, cultural difference, commitment, institutional environment, organizational culture, performance, international contractors, and construction. Of which, mainly top authors like Jiang L., Wang J., Wu P., Xu C., Liu J., Wang Y., and Skitmore M. have all touched on the respective keywords. The findings highlight key authors, keywords, and journals central to Construction, revealing major themes and influential researchers. This provides a roadmap for future studies and uncovers potential gaps in the literature, pointing researchers toward emerging or underexplored

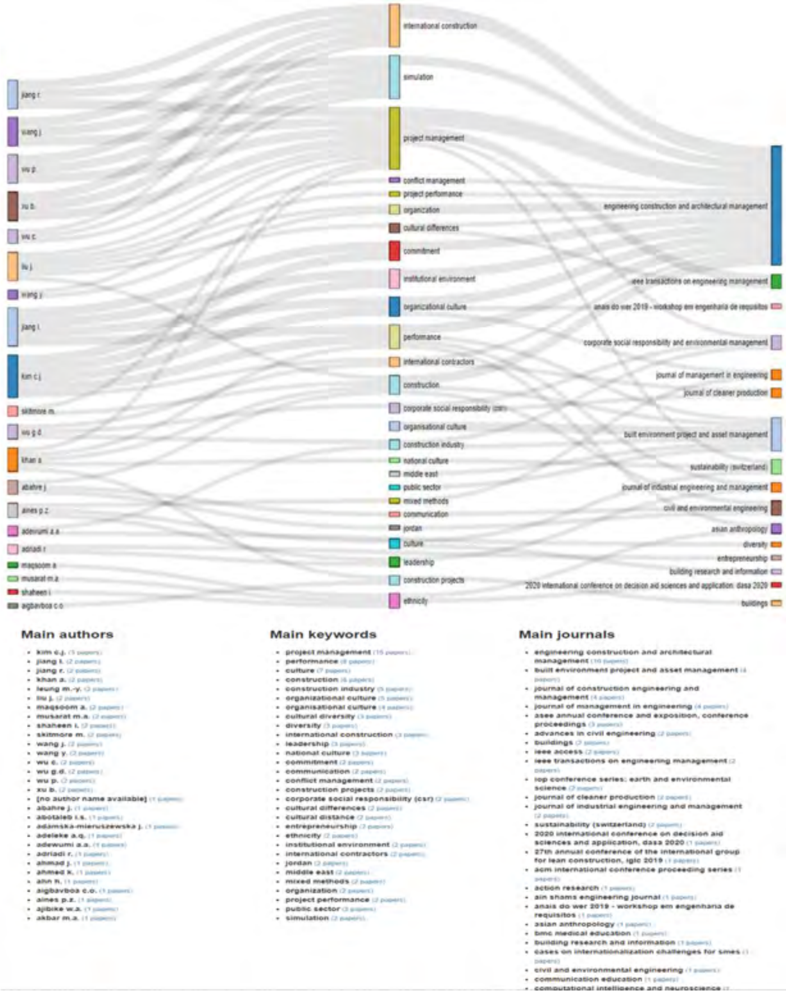

Figure 4. Association of top authors, keywords, and publishing journals. Source were adapted from Authors' source.

areas. The analysis shows interconnected authors and keywords, suggesting collaboration opportunities among researchers on related topics. Themes such as project management, conflict management, and cultural differences have practical implications, helping practitioners address challenges in international construction projects. Identifying "Engineering Construction and Architectural Management" as the leading journal guides researchers on where to publish for maximum impact.

2.5 *Network for citation document of cultural differences on project performance*

To further comprehend the conceptual framework of this study topic, a document citation analysis was performed. Table 1 and Figure 5 both depict the document citation network. Figure 5 illustrates the connection of different authors from the most cited documents and their relation to each other. However, it is noted that there is no close relation of the documents to each other in terms of collaboration. Table 1 further depicts the topmost frequently cited documents across the collected documents and portrays the links to each other as none. For this mapping, the minimum number of citations of a document was set at 5. Out of 95 documents, 32 met the threshold. Bamgbade *et al.*, (2019) shows to have the leading number of citations to be 50, followed by (Kowalczyk and Kucharska 2020) with 45 citations, (Shafiq *et al.* 2018) with 42 citations, and Wang *et al.*, (2020) with 21 citations. A total of 31 independent clusters were visualized in Figure 5 and depicted a total link of 1. Potential biases are also on the part of publications being more in developed countries compared to developed countries. Usually, resource allocations are based on publication records and citations. Therefore, the disparity shows more resources are allocated to more established research communities in developed countries hence widening the gap between them and developing countries.

Table 1. Citation document of cultural differences on project performance.

S/N	Authors	Citations	Title	Links
1	Bamgbade *et al.* (2019)	50	Analysis Of Some Factors Driving Ecological Sustainability In Construction Firms	0
2	Kowalczyk and Kucharska (2020)	45	Corporate Social Responsibility Practices Incomes And Outcomes: Stakeholders' Pressure, Culture, Employee Commitment, Corporate Reputation, And Brand Performance. A Polish-German Cross-Country Study	0
3	Shafiq *et al.* (2018)	42	Effect Of Project Management In Requirements Engineering And Requirements Change Management Process For Global Software Development (Shafiq *et al.* 2018)	0
4	El-adaway *et al.* (2018)	28	Contract Administration Guidelines For Public Infrastructure Projects In The United States And Saudi Arabia: Comparative Analysis Approach	0
5	Wang *et al.* (2020)	21	Ways To Improve The Project Management Efficiency In A Centralized Public Procurement System A Structural Equation Modeling Approach	0

Source: Author's Compilation.

3 DISCUSSION

The analysis identified that the number of publications in the field has increased, suggesting burgeoning interest. Developed countries dominated publications, highlighting an opportunity for research development in developing nations. Liu *et al.*, (2020) revealed that cultural

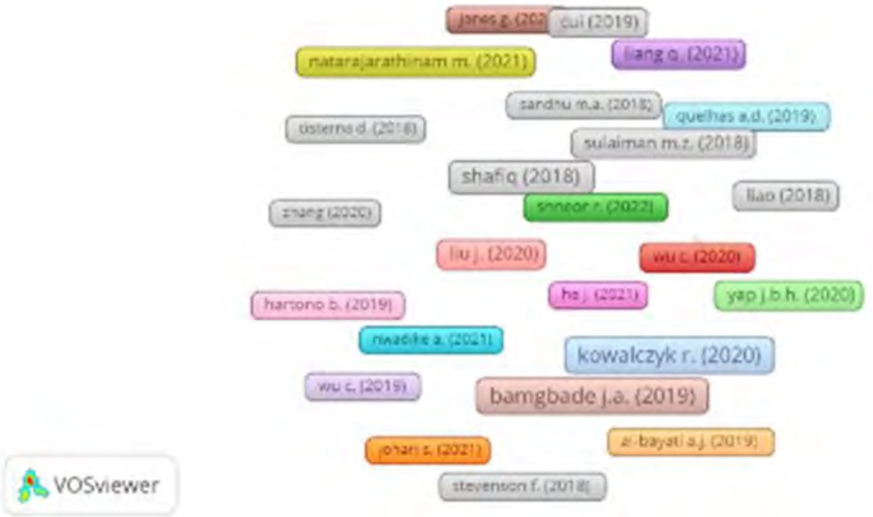

Figure 5. Citation document of cultural differences on project performance. Source: Made by the authors.

differences impacted project performance negatively in China and Korea while Rodríguez-Rivero, Ortiz-Marcos and Patiño-Arenas, (2022) found that cultural differences may not only cause conflicts in Latin America (Colombia and Ecuador), but also project management practices are more appropriate for some cultures not others. Additionally, Seiso, Ogunbayo and Aigbavboa, (2023) discovered that culture is one factor impacting project performance in joint ventures in South Africa leading to poor management control. This comparative literature between developed and developing countries reveals that project management practices differ from one region to another, however, there is room for project managers to improve and globalize the existing strategies to handle cultural differences in project dynamics. Collaboration across continents was limited, emphasizing the necessity for cross-collaborative efforts, especially in developing countries (Rantsatsi Ndaleni *et al.* 2020; Smits and Brownlow 2017). Therefore, global collaborations should be encouraged to foster ways to promote knowledge exchange and enhance research quality. Additionally, policy-makers should provide equity in research opportunities e.g. incentives for international collaborations and funds for researchers from underrepresented regions. Frequently used keywords include "Project performance," "Performance," "Construction Industry," and "Organizational Culture," which aid researchers in identifying key terms. Influential researchers in this field include Hofstede, G., Leung, Y.M., and Edwards, D.J., as by co-citation analysis. Authors Kowalczyk R. and Shafiq have notable citation counts, suggesting significant contributions to this topic area. These findings suggest that the exploration of cultural dynamics in project performance is still in its early stages. Similar studies have emphasized the integral role of cultural aspects in project settings (Wu *et al.* 2023; Zhao *et al.* 2018). The findings have clinical relevance in the field of project management, particularly in the construction industry, where understanding cultural differences can significantly impact project success

(Adewumi *et al.* 2022; Anglada 2022; Chileshe and Kavishe 2022; Cisterna *et al.* 2018; Cui *et al.* 2019; Collopy *et al.* 2022; Capobianco 2021; Davis and Pinto 2022; Federiakin 2020; Heldal *et al.* 2020; Jones *et al.* 2021; Kowalczyk and Kucharska 2020; Könning *et al.* 2021; Le 2024; Lenette *et al.* 2022; Lin *et al.* 2022; Liu *et al.* 2020; Lühr *et al.* 2022; Mangitung *et al.* 2022; Muthusamy and Che Adnan 2020; Popov and Karásek 2021; Rantsatsi Ndaleni *et al.* 2020; Rodríguez-Rivero *et al.* 2022; Samaraweera *et al.* 2018; Schmidt *et al.* 2020; Shneor *et al.* 2022; Seiso *et al.* 2023; Tembo *et al.* 2022; Yayla *et al.* 2023; Zhang *et al.*, 2020; Zhao *et al.* 2018). Alternatively, this data is crucial for enhancing the country's institutional research performance. It reveals that although the study area is emerging, there is a noticeable lack of contributions from developing regions, particularly Africa. Furthermore, it highlights a low level of research collaboration on cultural differences in project performance between African institutions and those in developed economies. This could be due to African institutions not perceiving the field as currently critical to their infrastructure discourse or a lack of essential resources such as cultural integration strategies and technical expertise needed to advance this research within African academia.

3.1 *Study limitations*

This study conducted a bibliometric analysis of papers on cultural differences in project performance from Scopus and Web of Science databases, covering 2018 to 2023 in English. Future research could use systematic or scoping reviews, additional databases, more years, and other languages for broader insights. There is a need to explore cultural impacts in large-scale construction projects, particularly civil projects. The limited scope highlights the necessity for comprehensive studies. This research offers valuable insights for practitioners and policymakers to improve project performance in culturally diverse environments. Emphasizing cross-collaborative research underscores the importance of global cooperation in managing cultural dynamics, and enhancing project management practices worldwide.

4 CONCLUSIONS

This study identifies trends, provides an intellectual framework, and suggests recommendations for further research, emphasizing the critical importance of managing cultural differences. The bibliometric analysis revealed a focus on building infrastructure projects, highlighting the need for deeper investigation into cultural impacts on civil projects, multinational teams, and work ethics. The lack of knowledge in developing countries on cultural differences in project performance can hinder effective management, undermining project success and organizational reputation. Considering cultural differences in project management can enhance project execution, quality outcomes, and stakeholder satisfaction, thereby improving the success of infrastructure development projects.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Exploring Corporate Social Responsibility (CSR) in the Zambian construction industry

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ABSTRACT: The study explored Corporate Social Responsibility (CSR) practices in Zambia's large construction firms. A survey found community and environmental initiatives to be most common. Benefits included better reputation and customer trust. Challenges identified in the study included limited budget, high cost, and lack of CSR guidelines. To improve CSR, the study suggests mandatory policies, a theoretical framework, and budget allocation for CSR initiatives. Further research could focus on developing a CSR framework and knowledge-based practices.

Keywords: benefits, challenges, construction, CSR, practices

1 INTRODUCTION

Corporate social responsibility (CSR) is a business concept that encourages companies to take responsibility for the impact they have on the environment, society, and the economy (Loosemore *et al.* 2016). CSR focuses on a company's commitment to operating ethically and sustainably while contributing to the well-being of the communities it interacts with (Zhang *et al.* 2018). Subsequently, the idea of CSR is broadly embraced across various areas where business exercises create generous cultural interests. As the result, the concept of CSR is widely adopted, the construction sector inclusive (Olanipekun and Darko 2020) . In spite of the fact that it starts from moral exercises, CSR has likewise been proposed as an elective long-term competitive advantage (Green *et al.* 2009; Larsen *et al.* 2012). Research into corporate social responsibility has always been the matter of scrutiny, either it being discussed lawfully or unlawfully and this has dated as early as 1950s (Kanji 2019). Most industries have known practices yet in Zambia practices of CSR are not well documented. A study done by Chongo *et al.* (2017) focused on the on motivation for CSR practice by small and medium enterprises (SMEs) while Kayula (2009) investigated the challenges of CSR. The study in both cases was for SMEs and not constructor sector specific. large scale firms were not investigated leaving a gap for this study to fill by studying the practices, benefits and challenges in the CSR for construction firms. The objectives of this paper therefore sought to find out the CSR practices, benefits, challenges, opportunies and threats in the Zambian Construction industry with the aim of improving practice.The paper extends prior research by highlighting current practice and its implication to the practising organisation. Furthermore, the threats and opportunies of CSR in the Zambian context are highlighted, this is novel as majority of studies in CSR focus of practices, benefit and challenges only.

The following section reviews the literature on the CSR focusing on practices, benefits and challenges. After which a methodology of the research is given followed by results and discussion. Finally, the study is concluded.

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1.1 *Corporate social responsibility and the construction industry*

Corporate social responsibility is an undeniable significant issue in the construction industry as networks, workers and socially aware customers anticipates that firms and construction companies should be acceptable corporate citizens (Lim 2017). The continuous advancement and extension of development of construction projects, nonetheless, is progressively connected with various practical improvement challenges, including environmental, social issues and monetary (Shen *et al.* 2010). The afforemention have prompted construction companies to participate in the manageability debate and begin formulating the management strategies to respond to the growing consideration from governments and the more extensive public to look after the environment they operate in. Firms in the UK are keen to show their thoughts about the environment by including "contribution to the society" in their vision statement while different firms in other nations are bound incorporate CSR issues in their sites just as a reaction to partners examination and pressing factors (Duman *et al.* 2016). In Nigeria, CSR is essential for the bigger commitment of the firm to its local area (Ekung *et al.* 2016). By adopting corporate social responsibility practices, construction enterprises can not only protect the interests of stakeholders but also contribute to sustainable development in various aspects such as organizational governance, environmental protection, and labor practices (Zhao and Ye 2019). Overall, CSR practices in the construction industry play a crucial role in promoting sustainability, environmental protection, and innovation. However, some argue that implementing CSR practices in the construction industry may lead to increased costs and reduced competitiveness (Duman *et al.* 2016). There is a belief that companies struggle to balance the implementation of CSR practices with the financial demands of construction projects where cost-effectiveness and profitability are cardinal (Lim and Loosemore 2017). Additionally, it is believed that diverting resources towards CSR initiatives could potentially hinder the growth and development of construction enterprises, particularly smaller firms with limited financial resources (Choongo *et al.* 2017). Moreover, opponents of widespread CSR implementation in the construction industry maintain that existing regulations and standards already address many of the social and environmental concerns, making additional CSR measures redundant (Huang 2017). They argue that strict adherence to existing regulations is sufficient to ensure responsible and sustainable construction practices.

The four main types of CSR include environmental, ethical, philanthropic, and economic (Carroll 2003). Environmental responsibility focuses on minimizing a company's negative impact on the environment. This can include practices such as reducing waste, conserving energy, and resources, and using renewable energy sources. Secondly, Ethical responsibility is about ensuring a company operates in a fair and ethical manner. This includes treating employees well, having a strong code of conduct, and sourcing materials responsibly. Thirdly, philanthropic responsibility refers to a company's efforts to give back to society through charitable donations, volunteering, and community development initiatives. Lastly, economic responsibility is about a company's commitment to operating in a financially sustainable way while also contributing to the economic well-being of the communities it operates in. This can include creating jobs, paying fair wages, and supporting local businesses two (Andrés *et al.* 2019). This does not only improve the lives of the workforce but the society at large (Lim and Loosemore 2017). However, in the construction industry Wang, Toppinen and Juslin (2013) divide CSR practice into environmental dimension which is mostly concentrated on waste and energy reduction at both the construction and operational stage, economical dimension which is directed CSR towards meeting the organization and agenda's from the stakeholders and lastly the social dimension is the Corporate social responsibility practices that are extremely fundamental on meeting the needs of the stakeholders. Notwithstanding other authors add a legal dimension to the practice of CSR. Legal responsibility talks about an organisation being socially mindful about their activities and operate within the confines of the law (Duman *et al.* 2016). While the ethical responsibility emphases on what is expected of the company by the society to assume and which responds to the ethical values that are founded in the society beyond what is required by the laws and regulation (Louche and Céline 2011).

The drivers of corporate social responsibility are divided into three categories namely the value driven approach, the stakeholder driven approach and the performance driven approach (Alizadeh 2022). The value driven approach talks about incorporating CSR as a way of increasing their profits although it's a self-motivated approach and depends on external pressures (Duman *et al.* 2016). The performance driven approach depends on the organization benefits in direct profits. It constitutes drivers such as company image and reputation (Govindan *et al.* 2014). Lastly the stakeholder driven approach Is aimed at meeting the stakeholders needs with the firm's performance (Zhang *et al.* 2018). Choongo et found that financial motivation, moral and ethics are the reasons why SMEs adopt community and environmental CSRin Zambia

The implementation of corporate social responsibility is aimed at achieving the business related strategy, the image building strategy, social strategy and the environmental strategy. In the business strategy Corporate social responsibility assumes that for a business to survive it has to have a social obligation and contact to act in selfless interest of an organization but act in the interest of the society (Loosemore *et al.* 2016). Many organisations incorporate corporate social responsibility as a way of smarten up the corporate identity and image of an Organisation (Duman *et al.* 2016). Loosemore *et al.* (2018) describes environmental strategies as actions taken to mitigate a company's negative operation impacts on the environment. Lastly the social strategy denotes the relationship between a company and communities affected by the operation of the organization (Fordham and Robinson 2018) this takes into account the expectations of stakeholders (Loosemore *et al.* 2018). The perceived benefits of incorporating corporate social responsibility in the construction industry includes improved image and reputation, maintaining the license to operate for company, minimizing costs from good environmental practices, improved customer loyalty and innovation and technology developments (Bevan *et al.* 2015; Ho and Shen 2017; Lawrence 2014; Lim 2017; Lin *et al.* 2018).

The lack of effective strategic forecasting for social responsibility, the huge cost and time obligation for implementing the CSR practices, On the other hand, there is lack of sensitization on the importance of the supply chain on environmental and social responsibility within the construction sector (Alotaibi *et al.* 2019), Heavily bureaucratic government rules and regulations is one of the barriers to CSR implementation (Olanipekun and Darko 2020) and Inadequate training and sceptic about the benefits of corporate social responsibility adds among other barriers to the implementation of CSR (Bux and Ahmad 2020) were identified as the barriers to the implementation of CSR.

In conclusion, the practice of CSR presents concerns however it is essential to recognize the long-term benefits of such initiatives, sustainable development, stakeholder interests, and the well-being of the community are all crucial factors that cannot be overlooked. Therefore, construction enterprises should make efforts to integrate CSR into their operations, despite the initial challenges posed. By doing so, enterprises can contribute to the overall advancement of society, the environment, and the construction industry. Perhaps, it is imperative for construction companies to find a balance between profitability and social responsibility, ensuring that both aspects are prioritized for the long-term success and sustainability of the construction industry. The next section discusses the methodology used in the study.

2 METHODOLOGY

The landscape of CSR in the construction industry is known in terms of how organizations practice CSR, the benefits of it and the challenges enterprises face. While there are gaps in knowledge in the Zambian context; much research has been done elsewhere as evidenced in the literature. A positivist approach was used in cross-sectional manner to establish the CSR practices, benefits and challenges faced. The population of this research comprised of -contractors and consultants as shown in Table 1 who indicated willingness to take part in the study. The contractors considered only those from grade 1 and 2 as these a large scale in nature. The consultants approached were those who had offered their services to such contractors as others had indicated that they had no capacity to practice CSR beyond what was legally tied to their employees. Additionally, in the Zambia consultants have no classifications as contractors are classified and graded by the national council for construction (NCC). The consultant's targets were architectural, Quantity surveying and Civil. Most of them offer a project management function.

Table 1. Organizations practicing CSR.

Name of respondent	Sampling method used	No of firms practicing CSR	Administered Questionnaires	Collected Questionnaires	Response Rate
Contractors (G1 and G2)	Purposive	26	20	12	60%
Consultants (Arc, Qs and Civil)	Snowballing	31	18	15	83%
Total		57	38	27	71%

A questionnaire was used as CSR as studies of this nature are many with clearly identified benefits, challenges, and practices (See literature section) while studies are many differences in legal, environmental, and general practices necessitated this research. Furthermore, Saunders *et al.* (2016) highlights ease of analysis and comparison compared to textual data, efficiency and anonymity of respondent, a broad reach, and easily quantifiable data as benefit of using a questionnaire. The questionnaire had closed questions and a few open-ended questions. It had two sections namely Section A demographic section and Section B had practices, benefits, and challenges. Practices and Challenges were based on a 5-point scale as follows 1=Always 2= Very often 3= Sometimes 4= Rarely 5=Never while for benefits the scale used was 1= Exceptionally beneficial 2= Very beneficial 3=slightly beneficial 4=beneficial 5= not beneficial. In the analysis closed questions were analyzed quantitatively using descriptive statistics (percentages, means etc.) and inferential statistics were not conducted due to the small sample size and non-random nature of the sample to guard against limited generalizability, reduced statistical power and difficulties in detecting small effects as examples. The results from the challenges and benefits were ranked to find out the level of utility these were later used to create a threats and opportunity matrix. A threat and opportunity matrix are a simple 2 x 2 grid that captures threat and opportunity of an activity, solution, or task. This was to classify the opportunities and benefits as internal or external to the organization in CSR Practice from the open-ended questions and closed responses done through a categorization by the researchers.

3 RESULTS AND DISCUSSION

3.1 *Characteristics of respondents*

There were twenty-seven respondents in total representing an overall response rate of 71%. The respondents comprised of two females and twenty-five males. Of these, one was aged between 20 and 25 and one aged between 35 to 40, those between 25 and 30 were nine, twelve were aged between 30 and 35, two were aged between 40 and 45 while those above 45 were two. In terms of the education background, two had a Diploma, eighteen had a first degree and seven had a master's degree. For working experience held; ten had worked experience between one and five years, twelve had worked for a range of 6 to 10 years, two for 11 to 15 years and two for between 16 and 20 years. All these had been spent in the construction industry. For the firm type, ten were local firms, mostly consulting firms while seventeen were foreign. For the contracting firms, the respondents held various positions namely Construction managers-3, Project managers-2, Foreman-4, and Site engineer-3. These enterprises offered work as follows Building works – 7, Civil engineering works-3, General works and building works-1, Civil engineering and building works-4. For consultants, the distribution was five Quantity surveyors, three Architects and four Civil engineers.

3.2 *CSR practices*

All the firms involved in the study indicated legal responsibilities such as paying workers wages, fair pricing, and medical assistance. The medical assistance is paid through the national health insurance and contributions to the workers compensation fund. These are legal responsibilities of an employer. Tables 2 and 3 show the other CSR practices.

Table 2. Community related responsibility.

Variables	Help Grow Skills in Community	Donate Cash to Charity org	Integrated the Disabled	Supporting Social Events (Sports, Art)	Supporting Economical and cultural Events	Giving Money and Materials	Supporting NGO's
				Consultant			
Mean	3.43	4.07	4.00	3.71	3.36	3.36	3.86
Median	3.50	4.00	4.00	4.00	3.00	4.00	4.00
Mode	3	4	4	4	3	4	3
Std. Dev	1.089	.829	.961	1.204	1.336	1.393	1.027
Rank	5	1	2	4	6	7	3
				Contractors			
Mean	2.78	3.11	3.00	3.22	2.78	2.89	3.11
Median	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Mode	2	3	3	3	2	1	3
Std. Deviation	1.093	0.782	1.323	0.972	0.833	1.537	0.782
Rank	7	2	4	1	6	5	3
				Overall			
Overall Mean	3.1	3.59	3.50	3.467	3.07	3.08	3.485
Overall Rank	5	1	2	4	7	6	3

Table 3. Environmental related responsibility.

Variables	Manages the environmental impacts of our business activities.	Improving energy efficiency in our products and services	Consider land use and biodiversity in its business decisions	Encourage and educates employees about sustainability and efficiency energy use	Using of green technologies that use fewer resources	Encourages the reuse and recycling of materials and minimization of waste
			Consultants			
Mean	3.36	3.07	2.79	2.43	2.21	2.14
Median	3.00	3.00	3.00	2.50	2.00	2.00
Mode	3	3	3	1	2	1
Std. Deviation	1.393	1.141	1.122	1.158	.699	1.099
Rank	1	2	3	4	5	6
			Contractors			
Mean	2.44	3.11	3.22	3.44	3.22	2.67

(*continued*)

Table 3. Continued

Variables	Manages the environmental impacts of our business activities.	Improving energy efficiency in our products and services	Consider land use and bio-diversity in its business decisions	Encourage and educates employees about sustainability and efficiency energy use	Using of green technologies that use fewer resources	Encourages the reuse and recycling of materials and minimization of waste
Median	2.00	3.00	4.00	4.00	3.00	3.00
Mode	2	3	4	4	2	1
Std. Deviation	0.527	1.167	1.302	1.333	1.093	1.500
Rank	5	4	3	1	2	6
			Overall			
Overall mean	2.90	3.09	3.01	2.94	2.72	2.41
Overall rank	4	1	2	3	5	6

Donating cash, integrating the disabled in society, supporting social events and supporting non-governmental organizations were the top four practices related to community related work as shown in Table 2. The construction related organizations seem to support what others are doing as opposed to supporting and promoting construction related activities such as design affordable materials or training on the use of sustainable designs, materials, and construction methods.

Loosemore, *et al.* (2018) in Singapore, Australia and New Zealand found practices more pronounced around environmental and safety issues while in the Zambia context practices is more focused on the community then the environment. This could be due to laws and regulations in the developing and developed contexts.

3.3 *Benefits and challenges of practising CSR*

The Practice of CSR has various challenges and benefits. The notable benefits for the two groups of respondents varied. The top four for contractors were reputational gain, an improvement in customer confidence, positive reaction from clients and a strengthened company image while for the consultants the top four benefits were a positive reaction from clients, reputational gain, strengthened company image, and new business opportunities. Reputational gain is the most common benefit for both contractors and consultants as brand recognition is the least benefit for both groups. The benefits are like the findings of Lawrence (2014), Bevan *et al.* (2015) and Zhang *et al.* (2018).

Table 4. Environmental related responsibility.

Variables	Manages the environmental impacts of our business activities.	Improving energy efficiency in our products and services	Consider land use and bio-diversity in its business decisions	Encourage and educates employees about sustainability and efficiency energy use	Using of green technologies that use fewer resources	Encourages the reuse and recycling of materials and minimization of waste
			Consultants			
Mean	3.36	3.07	2.79	2.43	2.21	2.14
Median	3.00	3.00	3.00	2.50	2.00	2.00
Mode	3	3	3	1	2	1
Std. Deviation	1.393	1.141	1.122	1.158	.699	1.099
Rank	1	2	3	4	5	6

(*continued*)

Table 4. Continued

Variables	Manages the environmental impacts of our business activities.	Improving energy efficiency in our products and services	Consider land use and biodiversity in its business decisions	Encourage and educates employees about sustainability and efficiency energy use	Using of green technologies that use fewer resources	Encourages the reuse and recycling of materials and minimization of waste
			Contractors			
Mean	2.44	3.11	3.22	3.44	3.22	2.67
Median	2.00	3.00	4.00	4.00	3.00	3.00
Mode	2	3	4	4	2	1
Std. Deviation	0.527	1.167	1.302	1.333	1.093	1.500
Rank	5	4	3	1	2	6
			Overall			
Overall mean	2.90	3.09	3.01	2.94	2.72	2.41
Overall rank	4	1	2	3	5	6

Various challenges were noted were noted by respondents in the Zambian construction industry. Firstly, CSR is not budgeted for as an activity possibly because it is costly as cost was ranked second. Contractors indicated that they were not aware of other methods of practicing CSR that hinged on the community and the environment and possibly because they lacked dialogue with their clients as this challenged was ranked at number four with clients being unaware of the practices they engaged in. For consultants, they also indicated a lack of knowledge on other practices they could engaged in as well as lack of dialogue with clients to be aware on what they practiced. The knowledge-based challenges as congruent with the findings of Bux and Ahmad (2020), nonetheless due to no clear national policy and regulations specific to CSR no such challenges were noted in comparision to the findings of Olanipekun and Darko (2020) who noted over regulation as a challenge to CSR practice.

Table 5. Benefits of practicing CSR.

Variables	Reputational Gain	Strengthened Company Image	Positive Reactions from Clients	New business opportunities	Boosting Employee Morale	Brand Re cognition	Improve Customer Confi dence	Comp etitiveness Improve ment
				Contractors				
Mean	3.85	3.23	3.38	2.85	3.31	2.08	3.62	2.92
Median	4.00	4.00	4.00	3.0	3.00	2.00	4.00	3.00
Mode	5.00	2.00	4.00	3.00	.2.00	1.00	4.00	4.00
Std. Dev	.986	1.32	.886	1.50	1.43	.500	1.33	.768
Rank	1	4	3	7	5	8	2	6
				Consultant				
Mean	3.33	3.33	3.47	3.33	3.00	3.20	3.00	3.20
Median	3.00	3.00	4.00	4.00	3.00	3.0	3.0	3.00
Mode	3.00	3.00	3.00	4.00	3.00	4.00	4.00	4.00
Std.Dev	1.045	0.789	1.33	1.00	.786	1.56	1.68	1.50
Rank	2	3	1	4	7	5	8	6
				Overall				
Overall mean	3.590	3.280	3.425	3.090	3.155	2.640	3.310	3.060
Overall rank	1	4	2	5	4	7	3	6

Table 6. Challenges of CSR practices utilization by construction organizations.

Variables	No Provision foo r CSR in Budget	Lack of knowl- edge by the cli- ents	Lack of Dialogue with Cli- ents	Lack of knowl- edge by contrac- tors/ consultants	Time related	Cost related (expen- sive)
			Contractors			
Means	3.33	3.1	2.89	2.11	1.67	3.11
Median	4.00	1.00	2.00	1.00	1.00	3.00
Mode	5	2	2	1	1	1
Std. Dev	0.86	1.20	1.23	.905	1.65	1.06
Rank	1	3	4	5	6	2
			Consultants			
Mean	4.20	1.8	3.90	2.80	1.80	4.10
Median	4.0	1.5	4.0	2.50	1.50	4.0
Mode	4	1	5	2	1	4
Std. Dev	1.43	1.50	.896	.500	1.20	1.00
Rank	1	5	3	4	6	2
			Overall			
Overall mean	3.765	2.450	3.395	2.455	1.735	3.605
Overall rank	1	5	3	4	6	2

More than 70% of the respondents indicated that the additional challenge to practicing CSR was the economic conditions, and few jobs available in the construction industry. Additionally, others indicated that CSR practices cost money and would therefore reduce their profit margins.

3.4 *Threats and opportunity analysis of CSR practice*

From the findings relating to benefits and challenges faced by contractors and consultants; threats and opportunities to the practice of CSR were identified as shown in Figure 1. The practice of CSR offers more opportunities than it does threats however the biggest threat is cost related followed by knowledge hinderance. This can be improved by firms having more projects and a conducive economic environment.

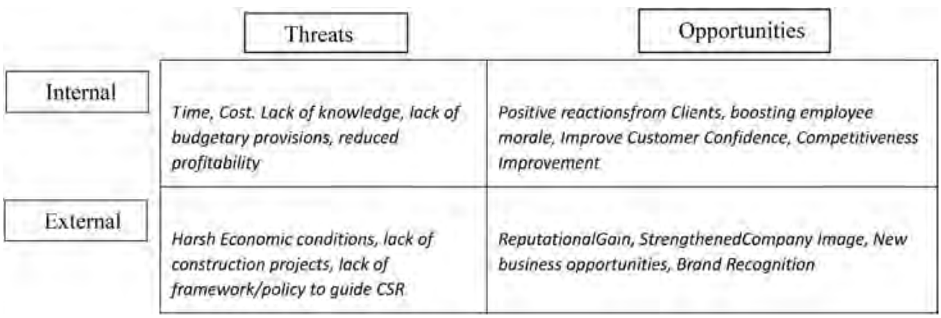

Figure 1. Threat and opportunity analysis of CSR practice.

4 CONCLUSIONS

CSR is a practice that benefits both the community and the practicing organization. The impacts could be to communities or the environment. Its practices come at a cost and the knowhow of its application. The firms in the ZCI would practice CSR better if they had budgetary allocation and increased their knowledge on how to offer CSR. Due to the aforementioned, organizations' do not seem to harness the opportunities of practicing CSR such as strengthened image, reputational gain, bossing of morale for employees and competitive advantage as examples A framework is needed to guide CSR practice in Zambia notwithstanding the fact that formulation of such as policy should not be burdensome on organizations. The opportunities to be harnessed from CSR practice are vast yet organizations need to have more projects and be more profitable to participate. Future research can focus on a policy of how construction related firms as well as others can offer CSR.

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Theme 9: Environmental & waste management

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Analysis of land use and land cover changes in Blantyre, Malawi

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ABSTRACT: The utilization of land in urban environments not only shapes the built environment but greatly changes and influences how people live and move. This therefore necessitates the need to investigate the land use and land cover changes to ensure sustainable development and efficient planning of cities. In this paper remotely sensed data from Landsat imageries of 1998, 2008, 2018, and 2023 were used together with GIS to analyze the spatial distribution of land use changes across the different time periods. The results indicated an increase in built up area and a decrease in bare land area between the years 1998 and 2023. During this period vegetation land was increasing slowly and began to decline steadily in 2008. This study provides a basis for effective urban planning and sustainable development strategies in the city of Blantyre.

Keywords: Land use, land cover, Blantyre, GIS, Sustainable development

1 INTRODUCTION

Urbanization as a force of transformation all around the world has set into place a new age of urban dynamics in which cities act as crucibles for cultural exchange, economic growth, and social transformation (Kone 2018). It is one of the main causes of land use and land cover changes because as population increases there is a growing demand for social and economic activities (Allan *et al.* 2022). This rising demand cannot keep up with the present infrastructure and so leads to unplanned changes in land use (Nath *et al.* 2021). These changes mainly lead to deforestation, biodiversity loss, global warming, and increases in the occurrence of natural disasters such as floods (Qiu *et al.* 2015). Sustainable land management practices can mitigate these impacts and promote conservation of the environment, enhancing resilience to climate change effects, and ensuring long-term food security (Gondwe *et al.* 2021). Therefore, analyzing the changes in land use and land cover can help policymakers and urban planners to make informed decisions.

The integration of remote sensing (RS) and geographical information systems (GIS) has become a prevalent approach in studying land use changes due to the advancements in satellite imaging. Various methods and techniques have been developed to accurately quantify and analyse these changes (Sahalu 2014). Remote sensing data sets are constant across large areas and over time, and they give information at a wide range of geographic scales. The information from remote sensing is very useful in describing an urban environment and how the landscape changes over time. Remote sensing and GIS techniques may be used to identify, map, and analyse physical patterns of urban expansion and sprawl. Within the GIS itself is a decision support system that analyses remote sensing and other geospatial datasets by utilizing multi-agent evaluation, which also can forecast future possibilities based on present and historical data (Bhatta 2012).

Geographical information system (GIS) plays a crucial role in the collection, retention, storing, and displaying of land use modifications. The classification procedure is employed

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to analyse Landsat images acquired during a certain time frame in order to correlate them with the temporal changes that have occurred. Satellite images are commonly employed to ascertain the characteristics and fundamental alterations in vegetation cover and the built environment. Some commonly used image sensors are Thematic Mapper (TM), Operational Land imager (OLI), Enhanced Thematic Mapper (ETM+), and Multispectral Scanner (MSS) to analyse and identify changes in land use within a specified timeframe. This choice is mostly due to the high level of spectral resolution generated by these instruments (Omoga 2020).

Malawi is a developing country in Sub-Saharan Africa with a population of 17,563,749 as recorded in 2018. The population has been increasing greatly over the past years. In 2018 the population was 1.3 times that of the 2008 population and four times that of the 1966 population (National Statistical Office 2019). These numbers show how Malawi is growing rapidly, especially in the urban areas. Urban areas in Malawi include the four main cities, namely Blantyre, Lilongwe, Zomba, and Mzuzu, and also other Bomas and towns. About 12% of the total population in 2018 lived in the four major urban areas. The urban population in Malawi has been increasing from 850,000 recorded in the year 1987 to 1,400,000 in the year 1998 to 2,000,000 in 2008 and finally 2,800,000 in the year 2018 (National Statistical Office 2019).

The population density in Malawi has also greatly increased over the years, with a density of 138 people/Km2 recorded in 2008 to 186 persons/Km2 in the year 2018. In Blantyre city, the population density was recorded as 3,334 persons/Km2 in 2018 which was an increase from 2,704 in 2008, this is the highest population density compared to Zomba, Lilongwe, and Mzuzu which recorded 2500, 2455 and 1516 person/Km2 respectively in 2018 (National Statistical Office 2019).

Over the years, studies on land use and land cover (LULC) change in Malawi have reflected this rapid urban growth. In 2020 a study by Mawenda indicated a great shift of land from vegetation and bare land to built-up area. A similar study by Gondwe in 2019 revealed that as the population increased there was a decrease in vegetation land due to the increased demand for timber, firewood, and infrastructure. These studies also highlighted that these changes in land use and land cover are a result of the poor management of urban growth which often leads to failures in the implementation of laws and policies. Gondwe studied the LULC change from 1999 to 2010 while Mawenda studied the changes from 1994 to 2018. By taking a period from 1998 to 2023, this study not only adds to this existing body of knowledge but also seeks to provide a more recent view of land use and land cover changes. This research makes a significant contribution by offering a comprehensive analysis over a 25-year period, utilizing advanced remote sensing and GIS techniques, thus providing policymakers and urban planners with crucial data to support sustainable development and effective urban management strategies.

The aim of this study is to analyze the land use and land cover changes by utilizing remotely sensed data and GIS for a 25-year period from 1998 to 2023. The remotely sensed datasets used are operational land imager (OLI) and Thematic Mapper (TM). The years selected for analysis throughout the 25-year study period are 1998, 2008, 2018, and 2023. The first three years were selected as they were the years in which the national census was conducted. This was to accurately examine how changes have been occurring in relation to population growth.

2 MATERIALS AND METHODS

2.1 *Remotely sensed data*

Table 1 shows the details of Landsat images collected over the 25-year study period.

Table 1. Landsat satellite images.

Satellite	Sensor	Path/row	Spatial resolution (m)	Date captured	Source
Landsat 5	TM	167/71	30	14 October, 1998	USGS
Landsat 5	TM	167/71	30	06 August, 2008	USGS
Landsat 8	OLI	167/71	30	19 September, 2018	USGS
Landsat 8	OLI	167/71	30	17 September, 2023	USGS

Landsat Operational Land Imager (OLI) and Landsat Thematic Mapper (TM) with 30m spatial resolution and a sixteen-day repeat cycle were the remote sensing datasets used for the study due to the high level of resolution they provide (Omoga 2020) (United Nations Geographical Survey 2024). Satellite images from 1998, 2008, 2018, and 2023 were downloaded from the United States Geological Survey (USGS) Earth Explorer. To enhance the visibility of images the data was obtained in the dry season as there are fewer clouds in the sky to distort the image captured. The near-anniversary dates were specially selected for consistency between the two time periods as well as consistency in lighting conditions, vegetation growth stages, and other environmental factors, thereby making it easier to compare the changes over time accurately.

2.2 *Image processing*

The satellite images were then corrected (atmospheric and radiometric correction) using the raster calculator in the ArcGIS software. By inputting the correction factors obtained in the downloaded data sets from USGS, the raster calculator then produced an output of corrected bands. This was done for each particular year. The corrected bands were then combined to form a composite band and arranged in accordance with the type C composite band as shown in Table 2.

Table 2. Spectral band composites for different Satellite images (Source: USGS).

Common Landsat Band RGB Composites			
Type	Color	Landsat 4-5 & Landsat 7	Landsat 8
A	Color Infrared	4,3,2	5,4,3
B	Natural color	3,2,1	4,3,2
C	False color	5,4,3	6,5,4
D	False color	7,5,3	7,6,4

2.3 *Image classification*

In the ArcGIS Software, the support vector machine (SVM) classifier was used to derive the four major classes of Land use Land cover (LULC), this was done in the supervised classification scheme. The Four major LULC classes include built-up area, bare land, vegetation, and water (Anderson *et al.* 1976). Built-up areas encompass various urban constructions such as industrial, residential, commercial, roads/highways, public installations, and similar facilities. Bare Land depicts unoccupied parcels of land, expansive spaces with minimal or nonexistent plant life, uncovered rocks, excavation sites, deforested hilly regions, and other unused and uncultivated land that is occasionally utilized for farming in violation of regulations. Vegetation on the other hand includes forests, parks, lands covered with trees, temporarily cultivated lands, grasslands, bushes, and other unused regions near streams.

Lastly, the water category encompasses permanent bodies of water, particularly those that are artificially created such as dams and ponds. Land use maps for 1998, 2008, 2018, and 2023 were then generated using the maximum likelihood supervised classification method. These maps will be used in the analysis of the LULC changes over the 25-year period.

2.4 *Accuracy assessment*

This is an essential step in LULC change classification process. The purpose of this accuracy assessment was to quantitatively evaluate how effectively pixels were assigned to the correct feature classes within the study area. This process involved comparing the classified results with geographically referenced data considered to be accurate. The analysis was conducted using ArcGIS software, where over 100 points were collected through stratified random sampling based on the sizes of the Land Use and Land Cover classes in the classified images for the respective years.

In this study, reference data for the years 1998, 2008, 2018, and 2023 was obtained from the Google Earth Image archives. Accuracy metrics, such as user's accuracy, producer's accuracy, and Kappa index, were calculated by generating the confusion matrix in ArcGIS. A Kappa value less than or equal to 0.4 indicates poor agreement, while a value between 0.4 and 0.8 indicates moderate agreement, and a value above 0.8 indicates excellent agreement (Foddy and Giles 2004). Table 3 gives a summary of the obtained accuracy assessment metrices from the confusion (error) matrices.

Table 3. Accuracy assessment for study years.

	YEAR							
	1998		2008		2018		2023	
LULC CLASS	P_ Accuracy	U_ Accuracy	P_ Accuracy	U_ Accuracy	P_ Accuracy	U_ Accuracy	P_ Accuracy	U_ Accuracy
Built-up area	100	70	87	90.9	89.7	92.9	86.8	100
Bare Land	89.7	100	90.9	92.6	87.5	98	95.3	89.1
Vegetation	90.4	100	78.6	91.7	94.7	85.7	81.8	85.7
Water	100	70	100	40	80	40	100	70
Overall accuracy (%)	91.8		87.3		89		90	
Keppa Index	0.86		0.81		0.83		0.85	

The overall accuracies obtained were 91.8%, 87.3%, 89% and 90% for the years 1998, 2008, 2018 and 2023 respectively. These values meet the minimum requirement set by USGS (i.e. greater than 85%) (Shao and Wu 2008). The kappa coefficient values obtained (i.e., 0.86, 0.81, 0.83, 0.85) show excellent agreement between the classified data and the ground data (referenced data) as they are all above 0.8. Therefore, these results show that the LULC maps are valid to be used for further analysis of LULC changes.

3 RESULTS AND DISCUSSIONS

3.1 *Land use land cover classification analysis*

The results from the four LULC maps indicate four classes of land use and land cover. Table 4 shows the area distribution and the proportion of the LULC classes. In the years 1998, 2008, 2018 and 2023 the class of built up gradually increased occupying an area of

46.99 km^2, 51.12 km^2, 66.77 km^2 and 78.57 km^2 respectively, representing 19.88%, 21.63%, 28.25%, 33.25% of the total area. Bare land was the largest class in all the study years and gradually decreased from 145.40 km^2 in 1998 to 129.51 km^2 in 2008, representing 61.52% and 54.80% of the total area respectively. It continued to reduce to 118.57 km^2 in the year 2018 covering 50.17% of the total area of Blantyre and finally coming down to 109.05 km^2 accounting for 46.14% of the total area in 2023. As for the class of vegetation, it occupied an area of 43.60 km^2, 55.05 km^2, 49.43 km^{2,} and 48.20 km^2 for the years 1998, 2008, 2018, and 2023 respectively which account for 18.45%, 23.29%, 20.92% and 20.39% of the total area in the respective years. Lastly, the class of water occupied the smallest area in all the years with 0.35 km2, 0.65 km2, 1.56 km^{2,} and 0.5 km^2 in the years 1998, 2008, 2018 and 2023 respectively, representing 0.15%, 0.27%, 0.66% and 0.21% of the total area.

Table 4. LULC area distribution and proportion for 1998, 2008, 2018 and 2023.

YEAR	1998		2008		2018		2023	
LULC Class	Area (sq.km)	%	Area (sq.km)	%	Area (sq.km)	%	Area (sq.km)	%
Built up	46.99	19.88%	51.12	21.63%	66.77	28.25%	78.57	33.25%
Bare Land	145.40	61.52%	129.51	54.80%	118.57	50.17%	109.05	46.14%
Vegetation	43.60	18.45%	55.05	23.29%	49.43	20.92%	48.20	20.39%
Water	0.35	0.15%	0.65	0.27%	1.56	0.66%	0.50	0.21%
Total	236.33	100.00%	236.33	100.00%	236.33	100.00%	236.33	100.00%

3.2 *Land use change detection analysis/post-classification*

The results for the post-classification for the first, second, third, and overall period are indicated in the transition matrices in Tables 5, 6, 7, and 8 respectively. In the first period (1998–2008) a total of 95.63 km^2 of the landscape experienced a change from one class to another while 140.5 km^2 persisted. In this first period, 25.39 km^2 was changed into built-up class representing 29.35% of the total change. In the second period (2008–2018) 172.62 km^2 of the landscape resisted change while 63.56 km^2 was changed with 25.39 km^2 being changed into built-up class accounting for 39.95% of the total change. In the third period (2018–2023) 182.73 km^2 of the landscape persisted any change while 53.44 km^2 experienced change. During this period 20.38 km^2 was changed into the built-up class representing 38.14% of the total change. The transition matrix of the overall study period from 1998 to 2023 indicated that 106.40 km^2 of the landscape underwent changes in land use and land cover while 129.73 km^2 resisted any change in the study area. This shows that 45.06% of the total area of Blantyre underwent a change in the 25-year study period and 46.65% of this change is attributed to the built-up class which accounts for 49.63 km^2 of the changed landscape.

3.2.1 *LULC change detection between 1998 and 2008*

In this period the built-up area had a net gain of 4.14 km^2 with a loss of 23.92 km^2 to other classes and 28.06 km^2 was converted from other classes to built-up class. Bare land experienced a net loss in this period of 15.87 km^2 as 47.17 km^2 was lost to other classes and 31.31 km^2 was changed from other classes to Bare land. There was an increase (net gain) in the vegetation class of 11.42 km^2 as 35.74 km^2 was changed from other classes into vegetation and 24.31 km^2 of vegetation class was lost and changed to other classes. The water class increased by 0.3 km^2 (net gain) as 0.22 km^2 was lost from the class to other classes and 0.52 km^2 was gained. The total change or transformation from one class to the other for this period was 40.50% of the total area of Blantyre. This was the highest recorded among all the study periods. The area that experienced LULC changes was 95.63 km^2 with Vegetation taking the greater part of 37.37% followed by bare land class with 32.74% then built-up class with 29.35% and lastly the water class with 0.54% of the total area of change.

Table 5. Transition matrix (1998–2008).

	LULC	Transition Matrix 2008 Km^2 Built-Up	Bare Land	Vegetation	Water	Total	Class loss	Net gain/loss
1998	Built up	23.04	14.44	9.42	0.06	46.96	23.92	4.14
	Bare Land	20.59	98.08	26.22	0.37	145.25	47.17	−15.87
	Vegetation	7.47	16.76	19.26	0.09	43.57	24.31	11.42
	Water	0.01	0.11	0.10	0.13	0.35	0.22	0.30
	Class total	51.10	129.39	54.99	0.65	236.13	95.63	
	Class Change (Gain)	28.06	31.31	35.74	0.52	95.63		
	% of class change	29.35%	32.74%	37.37%	0.54%	Total % Change	40.50%	

3.2.2 *LULC change detection between 2008 and 2018*

In the second period built up area continued to increase by gaining 25.39 km^2 and losing only 9.74 km^2 which represent a net gain of 15.65 km^2 making the annual growth rate 1.6 km^2/year as opposed to the previous period which recorded 0.4 km^2/year. This shows a rapid increase of built-up area class in the second study period. Bare land continued to reduce in this period with a 30.14 km^2 loss to other classes and only a 19.19 km^2 gain, representing a net loss of 10.95 km^2. Vegetation class also reduced in this period as 23.62 km^2 was lost and 18.01 km^2 was gained making a net loss of 5.61 km^2 in the vegetation class. The water bodies increased in this period with the gain of 0.96 km^2 and a loss of 0.06 km^2 making the area of water bodies increase by 0.91 km^2 (net gain). The total area of change in this period was 63.56 km^2 which is less compared to the previous study period. The change in LULC was mostly into built-up area with the class taking up 39.95% of the total area change followed by bare land with 30.2% then vegetation with 28.33% and lastly water class with 1.52% of the total area change.

Table 6. Transition matrix (2008–2018).

	LULC	Transition Matrix 2018 Km^2 Built Up	Bare Land	Vegetation	Water	Total	Class loss	Net gain/loss
2008	Built up	41.37	6.36	3.22	0.17	51.11	9.74	15.65
	Bare Land	15.26	99.28	14.75	0.13	129.42	30.14	−10.95
	Vegetation	10.13	12.82	31.38	0.67	55.00	23.62	−5.61
	Water	0.00	0.02	0.03	0.59	0.65	0.06	0.91
	Class total	66.75	118.47	49.39	1.55	236.17	63.56	
	Class Change (Gain)	25.39	19.19	18.01	0.96	63.56		
	% of class change	39.95%	30.20%	28.33%	1.52%	Total % Change	26.91%	

3.2.3 *LULC change detection between 2018 and 2023*

Built-up area continued to increase massively in this study period with a gain of 20.38 km^2 and a loss of 8.59 km^2 representing a net gain of 11.79 km^2 in just five years. The annual growth rate of built-up area (2.4 km^2/year) in this period is almost as twice as that of the previous period (1.6 km^2). Bare land class continued to decrease with a loss of 25.64 km^2 and only a gain of 16.13 km^2 making the class area reduce by 9.51 km^2 (net loss). The vegetation class made a net loss of 1.23 km^2 with a loss to other classes of 18.06 km^2 and a gain of 16.83 km^2. The water class decreased in this period by 1.05 km^2 (net loss) with a loss to other classes of 1.15 km^2 and a gain of 0.1 km^2. The total area change for this study period was 53.44 km2 with the built-up area taking 38.14% of total area change followed by vegetation class taking 31.49% then bare land with 30.19% and lastly water bodies with 0.18% of the total change area.

Table 7. Transition matrix (2018–2023).

		Transition Matrix						
		2023 Km^2						
	LULC	Built-Up	Bare Land	Vegetation	Water	Total	Class loss	Net gain/loss
2018	Built up	58.17	4.91	3.66	0.02	66.76	8.59	11.79
	Bare Land	12.67	92.82	12.95	0.02	118.46	25.64	−9.51
	Vegetation	7.36	10.65	31.33	0.05	49.40	18.06	−1.24
	Water	0.36	0.57	0.22	0.41	1.55	1.15	−1.05
	Class total	78.55	108.95	48.16	0.50	236.17	53.44	
	Class Change (Gain)	20.38	16.13	16.83	0.10	53.44		
	% of class change	38.14%	30.19%	31.49%	0.18%	Total % Change	22.63%	

3.2.4 *LULC change detection between 1998 and 2023*

For the overall time period, the built-up class increased greatly by 31.58 km^2 (net gain) with a loss of 18.05 km^2 and a massive gain of 49.63 km^2 which makes the annual growth rate of the built-up class 1.3 km^2/year. Bare land decreased (net loss) by 36.32 km2 with a loss of 61.13 km^2 and only a gain of 24.81 km^2. During this period vegetation had a net gain of 4.58 km^2 with a loss to other classes of 27 km^2 and a gain of 31.58 km^2. In this period the water class increased by 0.15 km^2 with a loss of 0.22 km2 and a gain of 0.37 km2. The total area of change for the overall study period was 106.40 km^2 representing a 45.06% change of the total area of Blantyre. The built-up area took most of the changing area with 46.65% followed by Vegetation with 31.58% then Bare land with 24.81% and lastly water with 0.35%.

Table 8. Transition matrix (1998–2023)

1998–2023		Transition Matrix						
		2023						
	LULC	Built-Up	Bare Land	Vegetation	Water	Total	Class loss	Net gain/loss
1998	Built up	28.91	10.23	7.75	0.08	46.96	18.05	31.58
	Bare Land	37.22	84.12	23.74	0.17	145.25	61.13	−36.32
	Vegetation	12.39	14.49	16.57	0.12	43.56	27.00	4.59
	Water	0.02	0.10	0.10	0.13	0.35	0.22	0.15
	Class total	78.54	108.93	48.15	0.50	236.12	106.40	
	Class Change	49.63	24.81	31.58	0.37	106.40		
	% of class change	46.65%	23.32%	29.69%	0.35%	Total % Change	45.06%	

3.2.5 *Population growth*

The population in the study area increased steadily from 502053 in 1998 to 648852 in 2008 and finally to 800264 in 2018 (National Statistical Office 2019). This population represented a growth of 29.24% from 1998 to 2008, 23.34% from 2008 to 1998 and an overall growth rate of 59.40% from 1998 to 2018. Table 9 gives a summary of the population data including the annual growth rates from 1998 to 2018.

Table 9. Population data (National Statistical Office).

Population Growth			Population Growth rate (%)			Annual growth rate (%)		
1998	2008	2018	1998-2008	2008-2018	1998-2018	1998-2008	1998-2008	1998-2018
502,053	648852	800264	29.24%	23.34%	59.40%	2.92%	2.33%	5.94%

4 DISCUSSION

The results from the post-classification show how the landscape of Blantyre has experienced drastic change over the past 25 years. Built-up area increased the most taking up 46.65% of the total LULC changes experienced in Blantyre between 1998 and 2023 (Table 8). This reveals that urbanization was one of the key driving factors of changes in LULC over the study period. These changes can be observed by the conversion of bare land and vegetation land into built-up areas (Table 8). The reduction in vegetation land is regarded as one of the characteristics that are associated with the increase in built-up area due to urbanization. This falls in line with a particular study done on the drivers of land use changes in Dedza, Malawi by Munthali *et al.* (2019), where it was discovered that built-up area had increased due to the development of forest land, agricultural land, and bare land for industrial, commercial and academic purposes (Munthali, *et al.* 2019).

The lack of implementation of the urban plans and policy regulations also contributed greatly to the increase of built-up areas resulting in the formation of informal settlements. Most of these settlements were conversion of areas into residential areas which initially were not intended for that purpose. This is similar to the findings of Mawanda *et al.* (2020), in which it was concluded that such transitions are a result of failures in the management of urban growth in the city. Population growth was also one of the causative factors of the increase in built-up areas as can be observed from the population growth which had increased greatly by 29.24% from 1998 to 2008 and 23.34% from 2008 to 2018 (Table 9). This was accompanied by an increase in population density of 2092/km^2 recorded in 1998 to 2704/km^2 in 2008 and finally to 3334 in 2018 (National Statistical Office 2019). Due to this population growth, there is an increase in the demand for residential land which leads to the conversion of vegetation and bare land into built-up areas.

As the socio-economic status of a city improves it becomes more convenient for people to live and build in the cities, this socio-economic growth also contributed to the increase in built-up areas. The increase in socioeconomic growth can be attributed to the change in the governance of Malawi in 1994 from a party state to multiparty democracy which enabled the population to run businesses in all cities of Malawi.

Vegetation land decreased steadily from 2008 to 2023 which mostly can be attributed to the encroachment by informal settlements resulting from urbanization. Conversion of vegetation to bare land has been the highest gain in bare land in all the time periods and the overall time periods (Tables 5,6 and 7), this can be attributed to practices such as deforestation. This loss in vegetation has repercussions on the environment as it decreases ecosystem services such as flood mitigation services, air and water purification, climate regulation, and noise reduction (Estoque and Murayama, 2013). Additionally, it degrades the soil, which results in the development of gullies and derelict landscapes.

5 LIMITATIONS

In this study, Landsat data used was Landsat 5 and Landsat 8 with a spatial resolution of 30m which implies that any changes below this pixel size may have been missed during the image classification process. Using high-degree satellite data and also advanced image pre-processing software could have produced more information about land use and land cover changes with great accuracy.

6 CONCLUSION

In LULC change detection analysis, remote sensing is the technology that is widely used. For this particular study, Landsat 5 TM and Landsat 8 OLI image datasets were used for the detection of changes in LULC. Maximum likelihood classification was used to produce LULC maps for the years 1998, 2008, 2018, and 2023, which were then used for the post-classification comparison method of change detection. The Kappa coefficients for the maps showed excellent agreement, and the overall accuracies were above the minimum requirement. The results from the post-classification show significant changes in LULC in Blantyre over the past 25 years. The results indicate an increase in built-up area, accompanied by a decrease in bare land. Vegetation land also decreased steadily between 2008 and 2023.

The driving factors of this LULC change have been identified as socio-economic growth, population growth, and poor planning and implementation of urban plans. This study provides valuable insights into the dynamics of urbanization and its impact on LULC changes over a 25-year period in Blantyre. The findings support the theoretical framework that links socio-economic growth, population increase, and inadequate urban planning to significant alterations in LULC patterns. By employing remote sensing technology and post-classification comparison methods, the research contributes to the growing body of literature emphasizing the importance of integrating advanced geospatial techniques for monitoring urban expansion and its environmental repercussions. Furthermore, the study underscores the necessity of considering socio-economic and demographic factors in urban planning and policy formulation to mitigate adverse environmental impacts.

The study also shows a transition from the vegetation class into bare land and from the bare land class into the built-up area. These findings can help urban planners and other stakeholders to make informed decisions ensuring urban sustainable development. To achieve this kind of development, it is recommended from this study that local authorities should ensure no delays in the allocation of suitable land for various developments. It is also recommended that the city should promote vertical development of commercial and residential buildings to fully utilize the available land. The study further recommends the drafting of city plans and development plans that are in line with the present LULC as well as the projected population. The city council should also consider formulating and implementing laws and strategies that make it almost impossible to evade the policies and laws while simultaneously not promoting encroachment of land. Sustainable development practices such as afforestation should also be highly promoted together with climate-smart agriculture techniques to help mitigate climate change impacts and enhance resilience.

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Utilizing wastewater treatment technologies to recover water for reuse: A review

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ABSTRACT: To develop standard effluents, resource recovery, and prevent overuse of finite freshwater resources, the globe seeks to investigate all wastewater treatment technologies that are now accessible in the face of water shortages. Municipal wastewater remains one of the primary anthropogenic causes for the discharge of contaminants of emerging concern (CECs) into the environment, which can have toxic and harmful impacts on aquatic creatures and by extension, on humans. This paper provides an overview of the cutting-edge and novel technologies that have become popular options for treating urban wastewater towards recovering water for reuse from various wastewater streams. Therefore, membranes, ozonation, activated carbon (AC), and photoelectrochemical technologies are discussed in this review for their potential as effective wastewater treatment choices. However, the consistent deployment and exploitation of all these technologies to address their flaws would, however, require close collaboration between engineers, analytical research scientists, and electrochemists.

Keywords: Biochemical oxygen demand, Biological treatment, Circular economy, Environmental sustainability, Resource recovery

1 INTRODUCTION

Organic and inorganic contaminants are commonly removed from municipal and industrial wastewater treatment facilities (WWTPs) effluents through physical, chemical, and biological treatment techniques (Aniyikaiye *et al.* 2019). As the human population grows, so does the amount of wastewater produced daily by houses, agriculture, and industry (Kasonga *et al.* 2021). The current world population, industrial expansion, and climate change are putting enormous strain on water supplies in terms of both quality and quantity, with water demands anticipated to rise by four hundred percent for manufacturing and one hundred thirty percent for home purposes by 2050 (Ibrahim *et al.* 2020). According to Jafarinejad (2020), treatment technologies are adapted so that wastewater effluents containing a broad range of bio-degradable organic matter, inert organic matter, suspended solids, pathogenic microorganisms, nutrients, and toxic substances are removed to protect public health, surface water, and recover resources such as energy and bio-fertilizers. As concerns about global

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climate change grow, energy efficiency optimization becomes increasingly important (Gu *et al.* 2017). The technology adaptation will be based on the influent concentration and effluent standards that meet the region's regulatory requirements, as superior treatment technologies will be required for treating high concentrated influents, whereas simplified treatment technologies can treat low concentrated influents but have limited benefits, such as unsuitability for resource recovery (Zhang *et al.* 2020). Environmental contamination caused by wastewater disposal and treatment has become one of the most serious issues in aquatic ecosystems around the world (Kumar *et al.* 2018). The environmental protection industry around the world continues to be hampered by the challenges caused by the massive amounts of wastewater discharged by various industrial sites (Mohamed *et al.* 2020).

Due to water shortages, depletion of water resources, and global warming, technologies to treat wastewater and create standard effluents as well as significant resource recovery as per standards have garnered worldwide attention (Ngo *et al.* 2019). These technologies are divided into conventional and advanced wastewater treatment systems (Shah *et al.* 2020).

It is currently well recognized that the adoption of sophisticated wastewater treatment technology minimizes the ecotoxicity effects of high-strength wastewater and pharmaceuticals and personal care products (PPCPs) as contaminants of emerging concern (CECs) (Zepon Tarpani and Azapagic 2018). In this review advanced biological treatment methods like membrane technology, ozonation, activated carbon (AC) treatment, and photoelectrochemical processes will be extracted and discussed as novel technologies that can be applied to reclaim water for later use.

2 MATERIALS AND METHODS

A systematic review technique was adopted in this review of advancements in wastewater treatment technologies. Databases such as web of science, science direct, springer scopus and google scholar were searched using keywords such as "Biochemical oxygen demand", "Biological treatment", "Resource recovery", "Wastewater treatment technologies", "Anaerobic-aerobic bioreactors", "Membrane technology", "Ozonation technology" "Activated carbon (AC) techno logy", "Electrochemical-based advanced oxidation processes (E-AOPs)" and "Photoelectro chemical technology". All published works that return keywords were identified after which those that describe various methods of wastewater treatment were retained and included in the review. A total of 146 articles were finally included in the review presented herein.

3 NOVEL TECHNIQUES FOR WATER RECOVERY

3.1 *Membrane technologies*

Membrane technology is one of the most effective ways to reduce environmental pollution caused by wastewater treatment plants (WWTPs) because of its high separation efficiency and relatively straightforward operational procedures (Abdel-Fatah *et al.* 2021). Before releasing effluents to the receiving water body, membrane filtration is frequently considered for the treatment of low and high-concentrated wastewater with contaminants of emerging concern (CEC), such as microplastics (MPs), produced from point sources (Khanzada *et al.* 2020). Membrane filtration is further acceptable if the separated component from the mixture is worthwhile relative to the cost of the filtration process (Anandkumar *et al.* 2021).

In advanced wastewater treatment, the removal of suspended solids (TSS) and microorganisms by creating a physical barrier are often the two main goals of the use of low-pressure membranes, such as microfiltration (MF) and ultrafiltration (UF) (Dharupaneedi *et al.* 2019). According to Rizzo *et al.* (2019), low-pressure membrane technologies typically recover between 96 and 98 percent of their water input from wastewater.

While UF is being used to treat wastewater from poultry slaughterhouses, 98 percent of suspended materials, 99 percent of lipids, and more than 94 percent of COD and BOD are eliminated (Yordanov 2010). The hydrophilicity and chemical resilience of the used polymer chemistries across a broad p^H range and oxidizing environments are common traits (Rizzo *et al.* 2019). These membranes are quite durable thanks to the material qualities and engineering design, which enable the use of hydraulic backwashing, air scouring, and soaking in a range of chemical solutions, including hypochlorite solutions, to retain their functionality and reversibly control fouling (Wu *et al.* 2021).

Reverse osmosis (RO) and nanofiltration (NF) are pressure-driven procedures that need more energy than other pressure-driven membrane-based treatment systems like microfiltration (MF) and ultrafiltration (UF) (Khanzada *et al.* 2020). On the other hand, NF and RO membranes typically function on water that has previously undergone pre-treatment and has a very low total suspended solids (TSS) concentration (Mukherjee *et al.* 2016). The usage of NF or RO for wastewater treatment and desalination has been continuously growing despite their high-pressure needs (Dharupaneedi *et al.* 2019). To effectively remove microplastics (MPs), which differ in size, charge, solubility, diffusivity, and hydrophobicity, from NF or RO processes, it is necessary to comprehend the basic principles at play, such as electrostatic interaction, size exclusion, and hydrophobic contact (Khanzada *et al.* 2020). Reverse osmosis (RO) can only pass-through water molecules and eliminate solutes and fine particles, but nanofiltration (NF) can sort and eliminate ions (Baker 2012). Reverse osmosis (RO) is well known for its effectiveness in removing tiny particles, like microorganisms, and monovalent ions like sodium ions and chloride ions, up to ninety-nine percent (Muro *et al.* 2012).

3.2 *Ozonation technology*

The ozonation process is an advanced technology that has seen widespread use around the globe (Wang and Chen 2020a). When utilized in chemical interactions with a wide variety of both organic and inorganic compounds, ozone is an extremely potent oxidizing agent (Ahmed *et al.* 2021; Malik *et al.* 2020). Ozone (O_3) has a wide range of applications due to its potent oxidative properties, including the oxidation of inorganic or organic molecules and disinfection (Ikhlaq *et al.* 2020; Wang and Chen 2020). Traditional methods for treating drinking water, such as coagulation-flocculation, filtration, and chlorination, are ineffective at removing contaminants of emerging concern (CEC), such as the widely used pesticide atrazine (Gomes *et al.* 2017; Wang *et al.* 2018). However, wastewater treatment can benefit from the information gained from drinking water treatment, but the matrix's variations must be taken into consideration (Rizzo *et al.* 2019). One of the advanced oxidation processes (AOPs), ozonation, effectively eliminates micropollutants and has a better overall environmental impact, which can improve wastewater reclamation (Arzate *et al.* 2019). Since no toxic byproducts are produced in the reactions involving ozone, this compound's use in wastewater treatment has been crucial for the past 10 years (Cuerda-Correa *et al.* 2020).

According to several studies conducted, utilizing ozonation to remove personal care and pharmaceutical compounds is quite effective because the majority of them can be eradicated (Ahmed *et al.* 2021). Although ozone has a short half-life, there is no doubting that it poses a concern if its concentration is higher than a particular threshold, which is close to 23 percent (Shen *et al.* 2019). According to very recent studies, ozone's oxidative ability to mineralize organic pollutants is not as effective as it is responsible for creating harmful byproducts, and it also has a low usage efficiency (Wang and Chen 2020b).

3.3 *Activated Carbon (AC) technology*

According to the size of the pores, activated carbon (AC) is divided into four categories: primary microporous with a pore size less than or equal to 0.8 nm, secondary microporous with pore size from 0.8 nm to 2 nm, mesoporous with pore size between 2 nm to 50 nm, and microporous with a pore size greater than or equal to 50 nm (Rizzo *et al.* 2019). Both granular activated carbon (GAC) and powdered activated carbon (PAC) are frequently used as forms of activated carbon (AC) in packed bed filters and contact reactors, respectively (Snyder *et al.* 2007). The presence of effluent organic matter (EOM), which interacts with the activated carbon molecule for binding and can plug pores, significantly reduces the effectiveness of activated carbon (AC) (Snyder *et al.* 2007).

The contact time for powdered activated carbon (PAC) and the empty bed contact time (EBCT) for granular activated carbon (GAC) regulate the adsorption processes (Rizzo *et al.* 2019). An adequate hydraulic contact time for the application of powdered activated carbon (PAC) is between 18 minutes and 3 hours (Kårelid *et al.* 2017). But by going back to the contact tank, powdered activated carbon (PAC) is kept in the reactor for a longer period (Siegrist *et al.* 2019). One advantage of using granular activated carbon (GAC) for treatment is that it may be added to deep bed reactors such as sand filters that already exist (Rizzo *et al.* 2019). For the same dissolved organic carbon (DOC) value and similar elimination of contaminants of emerging concern (CECs), earlier research has demonstrated that the activated carbon (AC) utilization is more for granular activated carbon (GAC) application compared to powdered activated carbon (PAC) (Kårelid *et al.* 2017). The granular activated carbon (GAC) dosage variations were much wider and varied up to 230 mg/L, depending on the carbon product, but the powdered activated system (PAC) system achieved a 95 percent clearance by providing a fresh dose of 15 to 20 mg/L (Kårelid *et al.* 2017). According to Boehler *et al.* (2012), when using an adsorption reactor with an empty bed contact time (EBCT) of roughly 10 to 15 minutes, it is shown that granular activated carbon (GAC) requires about three (3) to five (5) times more carbon than powdered activated carbon (PAC) for the equal removal of contaminants of emerging concern (CECs). Moreover, a 25-minute empty bed contact time (EBCT) was shown to be adequate for better performance for a 1.18 mm to 2.36 mm gradation at a low dissolved organic content (DOC) of 5 mg/L to 6 mg/L with carbon consumption comparable to that treatment using powdered activated carbon (PAC) (Wunderlin *et al.* 2017).

3.4 *Photoelectrochemical technology*

Photoelectron-Fenton (PEF), solar photoelectron-Fenton (PEF), photoelectrocatalysis (PEC), electro-peroxone (EP), photoelectro-peroxone (PEP), and other effective electrochemical technologies have recently emerged as novel electrochemical-based advanced oxidation processes (EAOPs) (Divyapriya *et al.* 2021). In addition to maximizing the benefits of synergistic effects, combining photochemical and electrolysis procedures also helps to reduce the drawbacks of each method separately (Ganiyu *et al.* 2018). Because such high treatability of the complicated wastewater can be attained with ease, the process efficiency can be easily controlled through automation, and the technology can be portable, occupying minimal space, electrochemical-based advanced oxidation processes (E-AOPs) are thought to be a promising next-generation alternative (Tang *et al.* 2019). The in-situ generation of hydroxyl (OH^-) radicals through an external power source is a component of electrochemical-based advanced oxidation processes (E-AOPs) (Miklos *et al.* 2018).

Photoelectron-Fenton (PEF) and solar photoelectron-Fenton (SPEF) processes are terms used to refer to electro-Fenton process studies carried out under the irradiation of artificial ultraviolet (UV) vis light and natural sunlight, respectively (Coria *et al.* 2018). Due to the cost-effective, environmentally benign method for removing all resistant organic pollutants, electro-Fenton-based methods have been receiving a lot of attention (Oturan *et al.* 2018). Anodic oxidation combined with photolysis is known as photoanodic oxidation, or photo-assisted anodic oxidation (Divyapriya *et al.* 2021). The common electrochemical-based advanced oxidation process (E-AOP) known as anodic oxidation produces radical species when oxidizing the water molecules on the anode surface or directly oxidizing the organic pollutant using the direct electron transfer (DET) technique (Martínez-Huitle and Panizza 2018). In the latest days, advanced research investigations have reported on using the hybrid electrolysis, ozonation, and ultraviolet (UV) induced photolysis technique known as photoelectro-peroxone (PEP) to remove persistent organic pollutants (Shen *et al.* 2017). In order to produce reactive oxygen species like peroxide (H_2O_2) and hydroxyl (OH^-), a process known as photoelectro-peroxone (PEP) primarily employs clean oxygen and electricity as its two main inputs (Divyapriya *et al.* 2021). Ozone (O_3) and peroxide (H_2O_2) are additional peroxone reagents that are activated by ultraviolet (UV) radiation without the need for a catalyst (Divyapriya *et al.* 2021). One of the sustainable techniques, photocatalytic fuel cell (PFC), uses photocatalytic reactions to simultaneously treat organic pollutants and recover energy (Zeng *et al.* 2018).

Due to the higher radical generation capacity and the improved degradation kinetics, combining the distinct photochemical, electrochemical, and photoelectrochemical processes into a single treatment unit has been shown to improve the system's capability to oxidize contaminants (Ganiyu *et al.* 2021). However, the findings produced in the published studies showed that photoelectrochemical techniques can be effective at treating washing liquids produced from soil remediation treatment (Ganiyu *et al.* 2018). The treatment depends on the working conditions for integrating photocatalysis and electrochemical technologies for soil washing remediation (Divyapriya *et al.* 2021).

4 CONCLUSION

Activated carbon (AC), membranes, ozonation, and photoelectrochemical technology are among the promising technologies that have been widely investigated for their relevance in wastewater treatment. Some contaminants of emerging concerns (CECs) may persist in effluents however after treatment and reach the environment after being transformed into more hazardous forms because of different interactions hence raising concerns for public health. Although CECs therapy technologies have significantly improved since they were initially found, their hazards have been established. For the elimination of most CECs, the effectiveness of various advanced treatment technologies, such as membrane, ozonation, activated carbon, and electrochemical-based advanced oxidation processes (E-AOPs), has been observed to be high. Even though hybrid systems are more effective than individual procedures at removing CECs and hazardous or harmful byproducts resulting from using an oxidant like ozone, concerns with energy, cost, time, and space availability continue to exist. However, the application of combined electrochemical-based advanced oxidation processes (EAOPs), a photoelectrochemical technology, is brightly promising but requires significant work for future developments. These developments will depend on the close cooperation of engineers, analytical research scientists, and electrochemists to achieve consistent implementation and exploitation of all these technologies.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Palestinian water resilience: A scoping review of adapting to climate change, shock events, and Israeli occupation pressures

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ABSTRACT: An ongoing bombing campaign by the Israeli Occupation has led to the assessment of the intricate intersection of Climate Change, Shock Events Impact, and Water Resources within the context of Infrastructure Development and Investment, with a particular focus on the challenges faced by Palestinian water resilience. Acknowledging the escalating frequency and intensity of climate-related shocks, the study scrutinizes the vulnerability of water infrastructure and its broader implications for sustainable development through a scoping review. This paper underscores the imperative of embedding climate resilience into infrastructure planning, highlighting the pivotal roles of innovative technologies, community engagement, and policy frameworks. By furnishing a comprehensive insight into the impediments posed by climate change, shock events, and occupation pressures on water resources in Palestine, this paper endeavours to offer guidance to stakeholders in formulating strategies conducive to bolstering infrastructure resilience and fostering sustainable water management practices and policies.

Keywords: Climate Change, Palestine, Shock Events, Water Resilience, Water Infrastructure

1 INTRODUCTION

The intersection of climate change, shock events impact, and water resources constitute a multifaceted and pressing issue with profound implications for both human societies and ecological systems. Climate change fundamentally alters the dynamics of the hydrological cycle, disrupting precipitation patterns, evaporation rates, and the frequency and intensity of extreme weather phenomena such as floods, droughts, hurricanes, and storms (Barhoum 2021). These changes significantly affect the availability, distribution, and quality of water resources worldwide. Shock events, exacerbated by climate change, further exacerbate these challenges, manifesting as sudden, severe disruptions to water systems and ecosystems. These events include natural disasters, environmental crises, and extreme weather occurrences, which can result in the contamination of drinking water sources, destruction of infrastructure, and disruption of water supply networks (Brandt 2020; Stamatopoulou-Robbins 2021). This study offers valuable insights that extend beyond the borders of the Middle East, resonating with infrastructure development needs in Africa. While the research focuses on the specific context of Palestine, the challenges of water scarcity, inadequate infrastructure, and vulnerability to shock events are not unique to the region. Similar challenges are prevalent across various regions of Africa, where rapid population growth, climate change, and political instability exacerbate vulnerabilities and hinder sustainable development efforts.

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Extreme weather events like floods and storms overwhelm water treatment facilities, releasing pollutants into water bodies and threatening human health and ecosystems (Hussein *et al.* 2024). These events worsen water scarcity in vulnerable regions without adequate clean water access and sanitation infrastructure. Droughts intensify agricultural losses, food insecurity, and social instability. Sea-level rise and saltwater intrusion further endanger coastal aquifers, freshwater ecosystems, and agricultural productivity (Eshtawi 2024; Salem and Ertz 2023). To address these challenges, strategies include improving water management, adopting water-efficient technologies, strengthening infrastructure resilience, and implementing early warning systems for extreme weather events.

1.1 *Rationale/problem statement*

The multifaceted challenges of water scarcity and resilience in the Palestinian territories have persisted since the onset of conflict in 1948 (New Straits Times 2023). These challenges necessitate a comprehensive examination due to several key factors. Firstly, acute water scarcity arises from limited resources and overexploitation exacerbated by the region's arid climate and growing demands from population growth, agriculture, and industry. Understanding water availability and usage dynamics is crucial for effective resilience strategies. Secondly, climate change intensifies these challenges through altered precipitation patterns, rising temperatures, and more frequent extreme weather events like droughts and floods. Addressing climate impacts on water availability, quality, and distribution requires urgent adaptation strategies. The Israeli occupation further complicates water issues by controlling resources, restricting access, and imposing limitations on infrastructure development and trade. This political dimension deepens inequities and complicates resilience efforts by Palestinians.

1.2 *Objectives*

Research objectives

(1) To systematically review the existing literature on the influence of climate change on water resources in the Palestinian territories, including changes in precipitation patterns, temperature, and extreme weather events.
(2) To analyse the impact of infrastructure development and investment on water resilience and socio-economic development in the Palestinian territories.
(3) To make policy recommendations for influencing sustainable policies that promote water resilience.

This paper critically examines the current water infrastructure situation as of 2023 – 2024 in Palestinian territories – The Gaza Strip and West Bank. The Palestinian territories are currently besieged and under occupation by the Israeli Defence Forces through the instruction of the Israeli Government. The implications of occupation stipulate that the territory will be controlled in all aspects of infrastructure and life – this has a significant impact on the population's access to basic services and influences Palestinians to seek immediate alternatives, especially in a conflict-riddled society (Abuzerr *et al.* 2020; Bar and Stang 2022).

2 SCOPING REVIEW

Climate change poses significant challenges to vulnerable regions worldwide, and Palestine is no exception. With its unique geopolitical context and environmental vulnerabilities, Palestine faces complex and multifaceted impacts from changing climate patterns (Bar and Stang 2022). Understanding the trends and projections of climate change in Palestine is crucial for informing adaptation and mitigation strategies, safeguarding natural resources, and enhancing resilience in the face of environmental risks. By synthesizing the available literature, this review aims to contribute to a deeper understanding of the water infrastructure dynamics in Palestine and provide insights for policymakers, researchers, and practitioners working to address the challenges posed by climate change and Israeli occupation in the region. Through rigorous analysis and critical evaluation of existing studies, this review identifies areas of consensus, divergent perspectives, and opportunities for future research and action in the Palestinian Territories.

2.1 *Examination of the increasing frequency and intensity of shock events*

The increasing frequency and intensity of shock events, such as droughts and floods, have become prominent features of the global climate system, posing significant challenges to societies, economies, and ecosystems (Alghariz and Mogheir 2023). This section of the literature review explores the empirical evidence, underlying mechanisms, and implications of these trends, with a focus on vulnerable regions like Palestine. Empirical Evidence is presented in numerous studies documenting a rise in the frequency and severity of shock events in the Middle East and North African region, including droughts, floods, and consequences of conflict (Abualtayef *et al.* 2022; Alghariz and Mogheir 2023; Sarsour and Nagabhatla 2022). Analysis of historical climate data reveals trends of more frequent and intense extreme weather events over recent decades. For example, research conducted by Rudolph (2020) illustrates a notable increase in the occurrence of droughts in arid and semi-arid regions, while Tayeh (2022) highlights a rise in the frequency of heavy flooding and poor infrastructure maintenance resulting in urban decay.

Underlying Mechanisms are presented by the intensification of shock events that are attributed to a combination of natural variability and human-induced climate change, using nuclear force and deliberate measures to reduce air quality and crop quality, the highly populated urban areas of the Levant experience crisis (Raby 2023; Schillinger *et al.* 2022). Climate models suggest that rising global temperatures alter atmospheric circulation patterns, leading to changes in precipitation distribution and intensity (Schär and Geldermann 2022; Tayeh 2022), anthropogenic factors such as deforestation, land-use changes, and greenhouse gas emissions exacerbate the frequency and severity of extreme weather events by amplifying atmospheric instability and moisture content (Rudolph 2020; Talhami and Zeitoun 2020). The implications for Vulnerable Regions, including Palestine, are disproportionately affected by the increasing frequency and intensity of shock events (Schillinger and Özerol 2023). Droughts and water scarcity exacerbate existing challenges related to agricultural productivity, food security, and freshwater availability (Al-Saidi *et al.* 2020; Alnajar *et al.* 2023). In contrast, floods pose risks to infrastructure, public health, and livelihoods, particularly in densely populated urban areas and low-lying coastal regions. The impacts of these shock events are often magnified in regions with limited adaptive capacity, inadequate infrastructure, and socio-economic disparities (Dadouch *et al.* 2023; Kearney *et al.* 2024).

Addressing the challenges posed by the increasing frequency and intensity of shock events requires comprehensive adaptation and resilience-building strategies which should include investments in early warning systems, disaster preparedness measures, sustainable land and water management practices, and infrastructure improvements designed to withstand extreme weather conditions however the implementation of sophisticated systems is hindered by socioeconomic conditions and the direct impact of occupation (Eshtawi 2024; Salem and Ertz 2023).

2.2 *Literature review table – scoping review*

Table 1. Condensed Literature review table. (Source: Author's work).

AUTHORS	YEAR	LOCATION	THEME	STUDY DESIGN	METHODS	FINDINGS
Schillinger, J., Özerol, G., and Heldeweg, M.	2022	Middle East	Armed conflict, water resources management	Case studies	Social-ecological systems perspective	Impact of armed conflict on water management, illustrated through case studies
Rantissi, T., Gitis, V., Zong, Z., and Hankins, N.	2024	Gaza	Water-energy nexus, systems approach	Advocacy	Qualitative analysis	Importance of a holistic approach in transforming water-energy nexus in Gaza
Buheji, M., and Al-Muhannadi, K.	2023	Gaza	Environmental risks mitigation	Review	Literature review	Precautions and solutions post-2023 war to mitigate environmental risks
Nagheeby, M., et al.	2023	Gaza	Water access, armed conflict	Advocacy	Policy analysis	Urgent need for equitable water access in Gaza amid weaponization of water
Barhoum, L.	2021	Gaza	Reconstruction efforts, water situation	Review	Documentary analysis	Evaluation of Gaza Reconstruction Mechanism and its impact on water infrastructure
Eshtawi, T. A., and Abdellatif, M.	2024	Gaza	Water service provider vulnerability	Assessment	GIS analysis	Identification of vulnerabilities in water service provision
Elnamrouty, K.A., and Al Madhoun, R. T.	2022	Gaza	Water service providers, Sustainable Development Goal 6	Analysis	Key performance indicators analysis	Progress and challenges in achieving SDG 6 in Gaza

2.3 *Implications of increasing frequency and intensity of shock events*

The increasing frequency and intensity of shock events have profound implications for water resources and infrastructure, particularly in vulnerable regions like Palestine (Nagheeby *et al.* 2023). These events place significant pressure on water management systems, worsening existing challenges and emphasizing the critical need for adaptive strategies and resilient infrastructure. Droughts significantly reduce water availability, exacerbating scarcity and threatening agriculture, ecosystems, and livelihoods (Rantissi *et al.* 2024). In Palestine, where water resources are already limited and face competing demands, prolonged droughts intensify pressures on groundwater and surface water sources (Buheji and Al-Muhannadi 2023). Reduced precipitation and higher evaporation rates further stress water resources, necessitating strict conservation measures and alternative supply options. Agriculture, a major water consumer, suffers during droughts and infrastructure failures, leading to crop failures, income loss, and food insecurity in dependent communities (Eshtawi and Abdellatif 2024; Zaqout *et al.* 2024). The implications of shock events on water availability and infrastructure highlight the urgent need for comprehensive adaptation and resilience measures (Brandt 2020; Stamatopoulou-Robbins 2021).

3 RESEARCH DESIGN AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines are an extension of the PRISMA statement specifically developed to guide the reporting of scoping reviews. Scoping reviews are a type of literature review that aims to map the existing literature in a particular field or topic area, identifying key concepts, theories, sources of evidence, and research gaps. PRISMA-ScR provides a structured framework for transparent and comprehensive reporting of scoping reviews to enhance their reproducibility and usefulness (Tricco *et al.* 2018).

3.1 *Study design*

This scoping review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines, which are specifically developed to guide the reporting of scoping reviews. Scoping reviews are a type of literature review aimed at mapping the existing literature in a particular field or topic area, identifying key concepts, theories, sources of evidence, and research gaps. PRISMA-ScR provides a structured framework for transparent and comprehensive reporting of scoping reviews to enhance their reproducibility and usefulness.

3.2 *Eligibility criteria*

The review includes studies focusing on Palestinian water management, climate change adaptation, resilience strategies, shock events (such as conflicts and natural disasters), and the impacts of Israeli occupation on water resources. Peer-reviewed articles, grey literature, reports, and policy documents published in English from 2020 to 2024 were considered eligible for inclusion. Studies that did not satisfy the study selection process were excluded.

3.3 *Search strategy*

A comprehensive search was conducted in electronic databases including Scopus, Web of Science, and Google Scholar. Keywords and terms related to "Palestine," "water management," "climate change," "resilience," "Israeli occupation," and "shock events" were used to ensure broad coverage of relevant literature. Studies outside of the keywords were not considered for inclusion.

3.4 *Study selection process*

The initial search yielded a large pool of articles, which were screened based on their titles and abstracts for relevance to the research topic. Nineteen full-text articles of relevant studies were then retrieved and assessed against the eligibility criteria as mapped in the literature review.

3.5 *Data extraction methods*

A standardized data extraction form was developed to systematically collect relevant information from included studies. Key data extracted included study characteristics (author, year, study design), population characteristics, intervention/exposure details, outcomes, and key findings related to Palestinian water resilience in the context of climate change, shock events, and Israeli occupation pressures.

3.6 *Quality appraisal or risk of bias assessment*

Given the exploratory nature of scoping reviews and the diverse methodologies of the included studies, formal quality appraisal or risk of bias assessment was not conducted. Instead, the focus was on comprehensively mapping the existing literature to identify trends, patterns, and gaps in research on Palestinian water resilience to inform better and more sustainable policy.

This scoping review employed a rigorous and systematic approach following PRISMA-ScR guidelines (Tricco *et al.* 2018) to identify and synthesize existing literature on Palestinian water resilience in the face of climate change, shock events, and Israeli occupation pressures. By adhering to these guidelines, this review ensures transparency, reproducibility, and usefulness in informing future research directions, policy development, and interventions aimed at enhancing water resilience in Palestine.

4 PRESENTATION OF RESULTS

4.1 *Importance of infrastructure development and investment in water resilience*

The water resilience challenges faced by Palestine share striking parallels with those encountered in various regions of Africa. Both regions grapple with similar issues stemming from conflict, political instability, and resource scarcity, which severely impact water infrastructure and access to clean water. In Palestine, as in parts of Africa, military offensives often target vital water supply infrastructure such as pipelines, wells, and treatment facilities, disrupting access to clean water for civilians. Similarly, terrorist attacks on water infrastructure in Africa cause damage and disruption, instilling fear and insecurity among communities and hindering repair efforts. Political instability resulting from coup attempts or assassinations further exacerbates water scarcity and pollution, echoing governance challenges faced by African nations in managing their water resources effectively (Brandt 2020).

Infrastructure development and investment in water resilience are crucial for ensuring sustainability and security amidst climate change and population growth. These findings resonate with prior studies by Brandt (2020) and Stamatopoulou-Robbins (2021), who emphasized the pivotal role of infrastructure in facilitating water resource management and enhancing resilience against environmental stressors. Adequate infrastructure plays a pivotal role in facilitating the extraction, treatment, distribution, and management of water resources, thereby ensuring access to clean and reliable water supplies for human consumption, agriculture, industry, and ecosystem health. Robust infrastructure also enhances resilience against shocks and stresses, such as extreme weather events, floods, droughts, and pollution incidents, which can disrupt water systems and jeopardize water quality and availability (Hussein *et al.* 2024). Investments in water infrastructure encompass a wide range of initiatives, including the construction, rehabilitation, and maintenance of water supply and distribution networks, wastewater treatment facilities, stormwater management systems, reservoirs, dams, levees, and flood control structures (Abu Aisheh *et al.* 2021; Bar and Stang 2022). The development of decentralized water treatment and storage systems can improve resilience by diversifying water sources and reducing dependency on centralized infrastructure vulnerable to disruptions, which would require Palestine to have self-determination and be free of occupation (Barakat *et al.* 2020).

4.2 *Shock events influencing water resilience*

The impacts of shock events, such as conflict and occupation, on water resilience have been underscored by previous research, Sarsour and Nagabhatla (2022), and Buheji and Mushimiyimana (2023) have documented the profound disruptions caused by military offensives and political instability, highlighting the urgent need for adaptive strategies in conflict-affected regions like Palestine. These occurrences exert significant impacts on the involved parties and the broader geopolitical landscape. Military offensives, whether initiated independently or in response to provocations, result in rapid territorial shifts, altering power dynamics and strategic calculations. Attempts to overthrow governments or assassinate political leaders destabilize institutions, potentially sparking political turmoil, power vacuums, and even civil wars. Mass casualty incidents, such as massacres or genocides, provoke international outrage and humanitarian crises, intensifying calls for intervention (Eid 2023). The sudden occupation or annexation of territory challenges the sovereignty and established borders, often inciting resistance movements or interstate conflicts, additionally, the use of weapons of mass destruction amplifies devastation, raising the spectre of broader escalation and catastrophic consequences (Eid 2023; Thawaba 2019).

The impact of shock events on water resilience, seen in regions like Palestine and echoed across Africa, is profound and complex. During military offensives, critical water infrastructure such as pipelines, wells, and treatment facilities are often targeted or inadvertently damaged, disrupting access to clean water for civilians and hampering repair efforts amid ongoing hostilities. Political instability resulting from events like coup attempts or assassinations further disrupts governance structures responsible for managing water resources, impeding efforts to address scarcity and pollution (Buheji and Mushimiyimana 2023; Cominola *et al.* 2023). The use of weapons of mass destruction (WMDs) in conflict zones poses catastrophic consequences for water resources and public health. Contamination with chemical or biological agents renders water sources unsafe, leading to widespread illness and death. In Palestine, where water resources are already scarce and subject to political disputes, these events exacerbate existing challenges and hinder efforts to achieve water security and resilience.

4.3 *Palestinian water resilience*

Building on insights from the literature, the findings illuminate the multifaceted challenges facing Palestinian water resilience. Studies by Al-Saidi, Roach, and Al-Saeedi (2020), Alnajar, Al-Najar, and Almadhoun (2023), and Dadouch, Balousha, and Berger (2023) have previously identified issues related to water scarcity, unequal access, and inadequate infrastructure in the region. By contextualizing the findings within this existing body of research, we elucidate the complex interplay of political, social, and environmental factors shaping water resilience in Palestine. Palestinian territories, including the West Bank and Gaza Strip, confront severe water scarcity, unequal access to water resources, inadequate infrastructure, and persistent geopolitical tensions, which exacerbate vulnerabilities and undermine efforts to achieve water security and resilience (Al-Saidi *et al.* 2020; Alnajar *et al.* 2023; Dadouch *et al.* 2023).

One of the central challenges in Palestine is the unequal distribution of water resources, largely controlled and allocated by Israel due to historical agreements and power disparities (Schillinger and Özerol 2023). Palestinians face limited access to water for domestic, agricultural, and industrial purposes. Restrictions on drilling wells, constructing water infrastructure, and accessing groundwater reserves, particularly in Area C of the West Bank under full Israeli control, exacerbate this disparity (Schillinger and Özerol 2023). Groundwater sources suffer from overexploitation, pollution, and contamination in Palestinian communities, with the Gaza Strip facing severe issues like seawater intrusion and unfit water sources (Buheji and Hasan 2024; Rudolph 2020). Infrastructure degradation, including ageing pipelines and inadequate sewage treatment plants, further compromises water resilience (Rudolph 2020). Hindered by restrictions on construction materials and equipment imports, efforts to maintain and rehabilitate infrastructure and improve water service reliability are impeded (Rudolph 2020; Talhami and Zeitoun 2020).

4.3.1 *Practical implications*

The study emphasizes the critical need for investing in infrastructure upgrades, such as flood protection systems, wastewater treatment plants, and decentralized water storage facilities, to fortify water systems against the adverse impacts of shock events, as underscored by Eshtawi and Abdellatif (2024). Integrated water management approaches are identified as indispensable in addressing the complex interplay between climate change, political pressures, and water resilience, urging policymakers to prioritize conservation, efficiency, and equitable distribution of water resources, as advocated by insights from Brandt (2020) and Stamatopoulou-Robbins (2021). Urgent policy interventions are highlighted to ensure fair distribution of water resources, particularly in Gaza, where water access is compromised amid the weaponization of water, emphasizing the development of frameworks addressing structural inequalities and upholding the rights of marginalized communities, as advocated by Nagheeby *et al.* (2023). The study stresses the importance of implementing precautionary measures post-2023 war to mitigate environmental risks, including sustainable land management practices, pollution control measures, and ecosystem restoration efforts to safeguard water resources and mitigate environmental degradation, as elucidated in the review by Buheji and Al-Muhannadi (2023).

4.4 *Policy recommendations*

Policy recommendations draw upon insights from past studies to inform actionable strategies for enhancing water resilience in Palestine. By aligning with the recommendations proposed by Barakat *et al.* (2020), Schillinger and Özerol (2023), and Abu Aisheh *et al.* (2021), this study builds upon existing knowledge and promotes coherence in policy formulation and implementation.

Table 2. Policy recommendations and implementations (Source: Author's work).

Policy Recommendation	Implementation Steps
1. Efficient Water Management	- Conduct water audits to identify wastage areas and implement conservation measures. - Upgrade infrastructure for leakage reduction. - Promote water-efficient technologies and practices among households, agriculture, and industry.
2. Integrated Water Resource Management	- Develop a comprehensive water management plan involving all stakeholders. - Establish water allocation mechanisms considering competing demands. - Implement rainwater harvesting and groundwater recharge initiatives.
3. Water Infrastructure Upgrades	- Prioritize repair and maintenance of existing infrastructure. - Invest in new infrastructure for water storage, treatment, and distribution. - Implement decentralized wastewater treatment systems.

5 SUMMARY AND CONCLUSION

This paper has addressed critical aspects of water resilience in the Palestinian territories by systematically reviewing the existing literature on the influence of climate change and shock events on water resources and analysing the impact of infrastructure development and investment. Through the review of literature, it has been elucidated how climate change is exacerbating water scarcity in the region through alterations in precipitation patterns, temperature shifts, and an increase in extreme weather events with the additional pressure of the occupation – the region struggles to meet demand (Rudolph 2020; Schär and Geldermann 2022; Tayeh 2022). Cross-regional collaboration offers African nations an invaluable opportunity to learn from the experiences and strategies employed in Palestine to protect water infrastructure and enhance resilience in conflict-affected areas, this research makes recommendations for improved policy and regional stability which is applicable and enforceable on a global scale. Drawing upon the findings of this analysis, several policy recommendations can be made to promote sustainable practices and enhance water resilience in the Palestinian territories. Firstly, there is a pressing need for coordinated efforts to mitigate the impacts of climate change on water resources through adaptive strategies, such as improving water efficiency, investing in alternative water sources, and implementing robust monitoring and early warning systems (Schillinger *et al.* 2022; Raby 2023). Secondly, policies should prioritize equitable access to water infrastructure and services, particularly for marginalized communities, while ensuring the sustainability of water management practices (Tayeh 2022). Lastly, fostering partnerships between government agencies, civil society organizations, and international stakeholders can facilitate knowledge exchange, capacity building, and resource mobilization to address the complex challenges facing water resilience in the region (Rudolph 2020; Talhami and Zeitoun 2020; Schillinger and Özerol 2023).

While the scoping review conducted in this paper has provided valuable insights into the influence of climate change and shock events on water resources and the impact of infrastructure development on water resilience and socio-economic development in the Palestinian territories, it is important to acknowledge a notable gap in research regarding the intersection of conflict, occupation, and war in these territories. The existing literature often fails to adequately address the unique challenges posed by the ongoing Israeli-Palestinian conflict and occupation on water resilience. The political dynamics, restrictions on movement and access, and the destruction or disruption of water infrastructure due to conflict and war significantly impact water availability, quality, and management in the Palestinian territories. Ultimately, a concerted effort is needed to translate the recommendations offered in this study into actionable policies and practices that prioritize the well-being of Palestinian communities and safeguard the region's precious water resources for future generations.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Climate change and disaster resilience: A case study of the April 2022 floods in Deelpan, North-West province, South Africa

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ABSTRACT: Building resilient and sustainable communities requires serious spatial planning and land use management consideration. However, because infrastructure is significantly impacted, the built environment community faces a serious challenge because of climate change. Thus, one of the strategies to reduce the impact of climate change on already existing infrastructure is through spatial planning. The primary goal of this project is to raise awareness of the significance of spatial planning in rural areas for disaster resilience since inadequate planning can have a detrimental effect on infrastructure. Additionally, the Spatial Planning and Land Use Act 2013 has noted that traditional land use development processes are poorly integrated into the formal systems of spatial planning and land use management. A study using a qualitative method based on an explanatory approach was conducted. The results showed that spatial planning is crucial for reducing the potential effects of climate change on current infrastructure.

Keywords: Climate change, disaster management, disaster, spatial planning, land use

1 INTRODUCTION

Spatial planning and land use management are crucial for creating resilient and sustainable communities. These tools play a vital role throughout the disaster cycle (Triantis 2023:30). In South Africa, the Spatial Planning and Land Use Management Act 2013 (SPLUMA) requires the incremental introduction of land use management in areas under traditional leadership, rural areas, and informal settlements (SPLUMA 2013:36). Historically, municipal planners had limited authority in these areas, despite their jurisdiction (Constitution of the Republic of South Africa 1996:74).

Climate change, defined by the Intergovernmental Panel on Climate Change (IPCC) as a persistent change in climate patterns (United Nations Framework Convention on Climate Change 2011), poses significant challenges for rural spatial planning. The impacts of climate change are experienced worldwide (United Nations 2019:2). In rural areas, the relationship between municipal planners and traditional leaders plays a significant role in spatial planning.

The effects of global warming, including increased rainfall and severe floods (Avand *et al.* 2021:1) put the well-being and sustainable development of rural communities like Deelpan in the North West province of South Africa at risk. This study examined the impact of the catastrophic floods that struck Deelpan in April 2022, exploring the challenges faced by residents, the response of the Tswaing Local Municipality, the role of traditional leaders, and key takeaways for rural spatial planning.

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2 LITERATURE REVIEW

All concepts covered in this paper are related to the research study. Understanding what each idea means is essential to understand the research topic better. Spatial planning, which involves the organization and design of physical spaces, is required to tackle the problems caused by climate change while striving for sustainability. Spurlock (2016), emphasized the vital role spatial planning can play in mitigating future climate change, including sustainable development, promoting resilience, and reducing greenhouse gas emissions across various sectors of society.

It entails a comprehensive method of land use that considers environmental, social, and economic factors (Reidsma *et al.* 2011). The research topic emphasizes or focuses on the impacts of climate change, particularly floods that hit Deelpan, a rural area in the North West province. This paper focuses on different concepts relevant to the research study by defining each of the impacts, and highlighting which is relevant. Furthermore, the paper focuses on the theoretical and conceptual frameworks by identifying and discussing the importance of its relevance to this study. This will assist in better understanding the research topic and understanding its relevance and significance.

3 CONCEPTUAL FRAMEWORK

This section outlines and defines different concepts relevant to the research study. Varpio *et al.* (2020:22) defined *conceptual framework* as a justification of why a given study should be conducted.

3.1 *Disaster*

Scholars have defined disasters in many ways: The American College of Emergency Physicians defined it as when the destructive effects of natural or man-made forces overwhelm the ability of a given area or community's ability to meet healthcare demands (Lomaglio *et al.* 2020:56). Carr (cited in Furedi 2007:483) argued that a disaster is defined by human beings and not by nature, indicating that not every windstorm or earth tremor is a catastrophe if there are no serious injuries, deaths or other severe losses. These definitions of a disaster are all centered around humanity, while the American College of Emergency based it more on healthcare, and Carr's definition is more on the effects of the disaster on lives.

Perry (2007) and Reinhardt (2015), cited in Reinhardt and Lutmar (2022:6), defined disasters as disruptions to society caused by unplanned events. Gaborit (2022) highlighted that climate-related disasters such as storms, floods, rising sea levels, cyclones, and dry spells are expected to increase in frequency, intensity, and impact. The unplanned events resulting from disasters and climate-related disasters call for a proactive approach at all levels of government, so that when a disaster strikes, mitigation plans are already in place.

3.2 *Disaster management*

Faulkner (2001), cited in Arora and Chakraborty (2021:675), defined disaster management as a multi-stage process requiring collaborative efforts of several stakeholders, each getting a small and often simultaneous time window to respond and contribute. Moreover, according to Harrald (2006), cited in Efendi *et al.* (2019:628), disaster management is defined as a phenomenon that requires both discipline and agility in the mobilization of forces and resources to anticipate the disaster, mitigate risks, and reduce the impact of post-disaster chaos, both for natural and artificial disasters. This study adopted both definitions of disaster management because it is indeed a multi-stage process, and it entails the mobilization of forces to anticipate a disaster. Anticipating a disaster and then having recovery plans shows the level of preparedness, and climate change impacts require immediate actions to reduce their severity.

3.3 *Climate change*

The IPCC (2011) defined climate change as an apparent change in the state of the climate (e.g., by using statistical tests) by variations in the average and the variability of its characteristics, and that lasts for a long time, usually decades or more (O'Neill 2017:22). This definition emphasizes that climate change involves changes in the long-term patterns and averages of temperature, precipitation, wind, and other climate-related factors. It recognizes that climate change can result from both natural processes and human activities, including the emission of greenhouse gases from deforestation, the burning of fossil fuels, and other human-caused changes to the Earth's systems. The definition also underscores that climate change is a persistent phenomenon that occurs over extended periods, distinguishing it from short-term fluctuations in weather patterns.

The effects of climate change, mostly in developing countries (Lucas *et al.* 2019:488), disproportionately affect poor rural areas. The Global Environmental Outlook 6 (GEO6) of 2019 and the Summary for Policy Makers in Climate Change and Land by the IPCC (2019) both stressed that climate change has worsened land degradation throughout the world, and this has been evident through natural disastrous events taking place such as the rise in sea levels, droughts, floods, and wildfires. This supports the IPCC's definition, emphasizing that the impacts of climate change persist for an extended period.

4 THEORETICAL FRAMEWORK

This section focuses on generating discussions of some of the concepts guiding this study. Varpio *et al.* (2020) defined a theoretical framework as a logically developed and connected set of concepts and premises, developed from one or more theories.

4.1 *Spatial planning in rural areas*

Spatial planning has been perceived as a delivery tool rather than a regulatory one (Medeiros 2019). Municipalities or local authorities must have spatial plans as tools to ensure sustainable development. These plans are not used in isolation, but together with other relevant planning policies, acts, and by-laws such as land use schemes, and intergraded development framework policies. The significance of spatial planning in rural areas lies in its ability to address the unique challenges and opportunities of these areas. These challenges include limited infrastructure, scarce resources, and balancing economic development with environmental conservation. This is why spatial planning is essential because it helps to tackle these challenges.

4.2 *Disasters in rural regions*

Disasters in rural areas can be both man-made and natural events that pose significant challenges and risks to the local communities (Furedi 2007). These disasters can be devastating for local communities due to their limited access to resources and services. The impacts of natural disasters in rural regions can be extensive, as these areas often have limited infrastructure and resources to withstand or recover from such events (Ahmed *et al.* 2019). The limited infrastructure and resources can exacerbate the damage and hinder recovery efforts. Rural areas face unique challenges in disaster management due to their remoteness (Paltemaa 2017), limited resources, and lower population density. Disaster management in rural areas is a complex and vital process that involves understanding the specific challenges faced by remote communities, developing appropriate strategies, and mobilizing adequate resources.

5 METHODOLOGY

The methodology employed a qualitative approach, which included interviews with a comprehensive desk review. Data collection involved conducting in-depth interviews with a diverse range of stakeholders, including Deelpan residents, representatives from the traditional authority, officials from the Tswaing Local Municipality, and rural community members. These interviews aimed at capturing personal narratives and insights into the lived experiences during and after floods, as well as the responses and roles of various authorities. The qualitative data gathered through these interviews provided a rich, nuanced understanding of the community's resilience and the effectiveness of the disaster response.

In addition to the interviews, a thorough desk review was conducted to analyze data from existing literature, including academic articles, policy documents, and books relevant to climate change, disaster resilience, and rural spatial planning. The findings from these sources were subjected to thematic analysis, a method that involves identifying, analyzing, and reporting patterns or themes within the data. This approach allowed for the synthesis of large amounts of qualitative information into coherent themes that reflect the broader implications of the floods. Furthermore, textual analysis was employed to critically evaluate the content of the literature review, ensuring a comprehensive understanding of the existing knowledge and contextual factors related to the April 2022 floods. This methodological framework facilitated a robust analysis of the impact of the disaster and the effectiveness of the community's and authorities' responses, ultimately contributing to the study's aim of enhancing disaster resilience in rural areas.

6 STUDY AREA

Deelpan is one of the rural areas under the Tswaing Local Municipality. which is rural. The local municipality falls under the Ngaka Modiri Molema District Municipality, which has offices in Mmabatho. Deelpan is located on a wetland that is unsuitable for residential development (Figure 1).

Figure 1. Deelpan, Tswaing local municipality (Source: Google Maps).

7 FINDINGS

7.1 *Lived experiences of Deelpan residents during and after the April 2022 floods hit the area*

It is important to identify the lived experiences of the community members during and after the floods, because it provided knowledge and insights into how well the community members were informed about activities taking place in their area. All residents spoke of how saddening and inconveniencing the floods were. The floods damaged most respondents' homes, while two respondents indicated that the floods damaged both their homes, businesses, and workplace. The traditional authority representative compared the April 2022 floods with the floods in 1987/88, and said these were more severe, and even caused much more damage to internal roads. The graph overleaf indicates responses based on the damage the floods caused.

Figure 2. Responses based on damages caused (Source: Authors 2023).

7.2 *Reaction of Tswaing Local Municipality to the floods during and after they hit the Deelpan area in April 2022*

From the officials who worked in Tswaing Local Municipality, it is evident that the aftermath of the floods came as a shock. They did not expect the area to be flooded, even though the planners mentioned that the place they currently occupy was unsuitable for development. Unfortunately, the municipality was not prepared for such a disaster because it did not have a disaster management unit.

The devastating events of the floods, which led the municipality to liaise with its District Municipality and other relevant departments for assistance, led to the decision to create a new disaster management department within the Tswaing Local Municipality. That unit will be responsible for having a disaster management plan in place for the municipality to avoid future disasters from occurring without the municipality being ready and prepared.

With all the efforts the municipality put in place, only the ward councilor knew what the municipality did. Most of the community members had a different view and said that their local municipality offered no assistance. Some of them were not even aware that the local municipality did not have a disaster management department. This raised concerns about the level of transparency in the local municipality to its community members.

7.3 *The role of traditional leaders during and after the April 2022 floods*

The representative from the traditional authority was an old woman with many insights about the area. She compared the April 2022 floods with the floods that took place in 1987/88. She also indicated that over the years, their community had grown, and suspected that the growth might have caused the severity of the floods compared to the 1987/88 floods. She recalled that the severe floods that occurred in 1987/88 did not cause any changes to the main big river and explained that after the April 2022 floods hit, their river has now grown, and she feared future floods.

The representative explained that as a traditional authority, the floods took them by surprise as they were not prepared for the devastating impacts that followed. She then indicated that the traditional authority donated land to the municipality to build houses for the community members affected by the floods.

7.4 *Implications of lack of rural spatial planning*

Spatial planning is essential, and rural spatial planning is of paramount importance as the lack of it can result in devastating events where rural community members find themselves in compromising situations beyond their control. These compromising situations are due to their limited infrastructure, lower population densities, and remote location in disaster management.

Furthermore, SPLUMA and all other relevant policies and legislation, speak one language of developing and improving the livelihoods of those living in rural areas in accessing basic infrastructure needs compared to those living in urban areas, who already have access to such infrastructure. All of the above will be possible with the implementation of spatial plans in rural areas. Spatial plans should incorporate disaster management plans unique to all areas under the Tswaing local municipality to ensure their effectiveness.

8 CONCLUSION AND RECOMMENDATIONS

The importance of spatial planning, especially now when the impacts of climate change are experienced all over, has no settlement boundaries, and every settlement needs to be formally planned to ensure disaster resilience and sustainability for future generational use. The following recommendations are presented to ensure that flood disaster management is incorporated in spatial plans to ensure disaster resilience and sustainability of settlements.

8.1 *Intersectoral collaboration*

The departments within the local municipality must start working hand in hand. The Town Planning Department needs to have relationships with the Housing Department, the Infrastructure Department, the Integrated Development Plan (IDP) Department, the Local Economic Department, and the Disaster Management Department. Their plans for all areas under their jurisdiction need to inform each other. Regular inspections need to be conducted, and as highlighted in Chapter 3 of the Constitution, 1996, the Municipal Systems Act, and SPLUMA, previously disadvantaged areas, such as rural areas under traditional authorities, need to be considered in all planning processes and the community needs to be involved in assisting the local municipality with ideas properly.

The local municipality also needs to liaise with other local municipalities and the district municipality to benchmark itself, to see what others are doing differently, what they can learn from others, and what they can offer because this will spark a proactive approach in their plans instead of a reactive mindset. This relationship should not be limited to only municipalities, but relevant government departments, such as the Department of Public Works and Roads, the Department of Human Settlements, and the Department of Health, should ensure that the infrastructure provision plans are in line with municipal needs.

8.2 *Good working relationship between municipal planners and the traditional authority*

These two need to be in constant communication regarding the future development of their area. This goes to all rural areas under the different traditional authorities in the Tswaing Local Municipality.

A committee consisting of representatives from the traditional authority needs to be established so that planning issues can be addressed and agreed upon before consultation is done with the community members. The findings are clear that the community members are more used to their traditional authority than their local municipality, and as a result, they will be more likely to listen, participate, and comment on development projects if they see that their traditional authority is involved.

Indigenous knowledge in tackling the impacts of climate change has proven to work over the years in some areas. A good working relationship will allow for the sharing of knowledge and exchange of knowledge in finding or developing mitigation and adaptation plans for future disasters such as floods, as it looks as if Deelpan will be one of the areas that experience devastation.

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Sanitation infrastructure challenges in informal settlements in Johannesburg: The need for resident's education and empowerment

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ABSTRACT: Informal settlements in South Africa are experiencing population growth as migrants move to urban areas in search of better living conditions. This migration results in issues like overcrowding, unsanitary conditions, pollution, water scarcity, and poor waste management. These issues negatively affect residents' health and contribute to broader problems like poverty. To address these challenges, a study was conducted in four informal settlements in Johannesburg using questionnaires. Data was collected through qualitative interviews, purposive sampling, and written materials. The data was analyzed using a stratified method, and a focus group was employed to increase the validity and reliability of the findings. The findings reveal the socioeconomic challenges residents face, including poverty, unemployment, illiteracy, and crime, as well as healthcare and education. To address these issues, there is a need for education and empowerment initiatives aimed at improving sanitation infrastructure and fostering healthier, more resilient communities in Johannesburg's informal settlements.

Keywords: Informal Settlements, Sanitation, Sanitation Infrastructure, Education, Johannesburg

1 INTRODUCTION

Urbanization, particularly in Johannesburg, has led to the rise of informal settlements (Bishoge 2021, pg. 7; Moll *et al.* 2019), causing environmental degradation and open defecation. In India, less than half of the population has access to toilet facilities, leading to over 10 million people resorting to open defecation daily (Tiwari *et al.* 2022). In Brazil, informal settlements house 6% of the population, facing significant sanitation infrastructure challenges due to low income and education levels (Diep *et al.* 2021). Government institutions have failed to provide adequate support or incentives for these communities, hindering the adoption of decentralized sanitation infrastructure (Ouma 2021). Malaysia prioritized sanitation infrastructure in 1957 with robust regulatory frameworks and private sector involvement (Kelkar 2018). In Johannesburg, South Africa, informal settlements are a harsh reality, housing many residents facing socio-economic and infrastructural challenges (Bishoge 2021,

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pg. 13). The lack of adequate sanitation infrastructure contributes to severe health issues, compromised well-being, and increased mortality rates (The Global Steering Group 2022).

2 SANITATION INFRASTRUCTURE AND ITS CHALLENGES IN INFORMAL SETTLEMENTS

Sanitation is a critical public health issue that involves access to safe drinking water, sewage treatment, and environmental cleanliness (Abrahams and Everatt 2019). It prevents diseases like roundworm infections and ensures hygienic conditions through waste management and wastewater disposal (David *et al.* 2020). Despite global efforts to improve sanitation infrastructure, a significant portion of the population still lacks basic sanitation services (Hewitt *et al.* 2020). Initiatives like the GH-GAMA Sanitation and Water Project in Ghana (World Bank 2020) and the Global Sanitation Fund in Nepal aim to address this issue (WHO 2020). However, challenges persist, particularly in informal settlements where sanitation infrastructure remains poor. Diarrhoea remains a leading cause of death among children under five globally (Ouma 2021). Key questions include initiatives to improve inadequate sanitation infrastructure, community responses, efforts to align improved sanitation with enhanced facilities, and necessary policy measures to promote sanitation improvement.

2.1 *Study area*

South Africa has over 2,700 informal settlements with a population of 4 to 5 million, largely due to apartheid policies (Hewitt *et al.* 2020). In 1994, the population exceeded 40 million, with 20.5 million lacking access to basic sanitation facilities (Strauss 2019). During the democratic era, an influx of migrants led to the need for affordable housing in urban centers like Cape Town, Durban, and Johannesburg (Hewitt *et al.* 2020). However, progress in sanitation infrastructure in informal settlements has been slow, with 18 million individuals lacking access to improved facilities in 2015 (Ouma 2021). An estimated 11 million South Africans still lack adequate sanitation, resorting to shared facilities, bucket toilets, or open defecation (Abrahams and Everatt 2019).

Figure 1. Unhealthy environment and inadequate sanitation facilities in informal settlements in Johannesburg. Source: Mail and Guardian Newspaper, July 2017.

In 2011, 91% of Johannesburg residents had access to chemical toilets and pit latrines, up from 83% in 2001 (McMichael 2019). However, South Africa's sewage infrastructure faces significant challenges, with a significant portion in disrepair (Motsoeneng 2022). Annual maintenance costs for sewage treatment plants are only 1% of their value, and only 60 of the 824 facilities discharge clean water (Abrahams and Everatt 2019). Additionally, 50,000 liters of raw sewage enter waterways every second, indicating a lack of maintenance culture (Mail and Guardian Newspaper, July 2017).

2.2 *The city of Johannesburg*

Johannesburg, South Africa's economic hub, has over 180 informal settlements with a growing population of 500,000 people and 224,189 households. Accurate data on these settlements is limited due to their proliferation (Nkambule 2020). In 2011, 125,748 households were in informal settlements, with 22% having higher access to sanitation infrastructure, 30% having basic access, and 48% lacking access (Muanda *et al.* 2020).

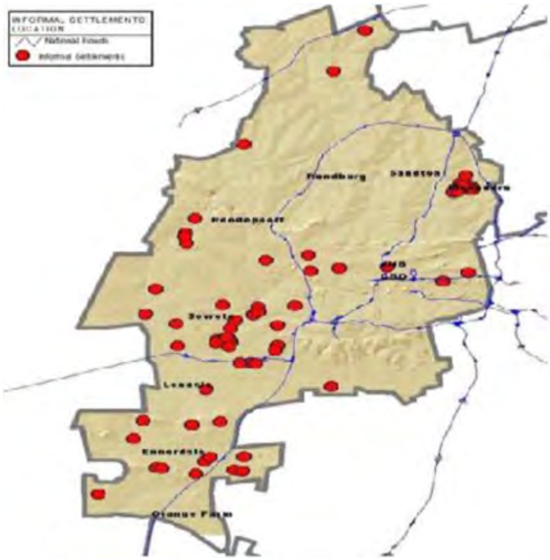

Figure 2. Map showing location of some informal settlements in Johannesburg; Source: City of Johannesburg.

Johannesburg's informal settlements, located around the city's periphery, are often impoverished and lack sanitation infrastructure (Adegun 2019). These areas are susceptible to natural disasters like floods, often experiencing groundwater recharge and elevated water tables (Adegun 2018). Many of the informal settlements in Johannesburg are situated along riverbanks and tributaries, lacking access to formal sewerage systems, highlighting the challenges faced by these urban dwellers (Williams *et al.* 2019).

3 RESEARCH METHODOLOGY

The study, conducted between October 2022 and June 2023 in Johannesburg, South Africa, aimed to investigate the challenges related to sanitation infrastructure in four informal settlements. The settlements were Sejwetla, Denver, George Goch, and Mangolongolo. Data was collected through surveys, semi-structured interviews, focus group discussions, observation, and a literature review. Quantitative surveys were conducted with 10 households in each settlement to explore specific challenges related to sanitary infrastructure. Systematic random sampling was used to select every 10th household from this list, resulting in a total of 10 households per settlement. Qualitative methods, including interviews, face-to-face interviews, and area observations, were employed to capture the lived experiences of respondents. Semi-structured interviews were conducted with 10 informants from each settlement, totalling 40 interviews. Four focus groups were conducted in each settlement, with 8–10 participants per group. These meetings were held in community centres, accessible venues within the settlements, and were conducted in either English or the vernacular language. Geo-spatial mapping techniques were used to visualize issues with sanitary facilities in these communities. Researchers visited the study locations over three months for first-hand observations and photographic assessments.

Figure 3. Informal settlements in Johannesburg; Source: Carruthers, Jane 2006.

4 FINDINGS AND DISCUSSION

The study highlights the socioeconomic challenges faced by Johannesburg's informal settlement residents and the negative effects of inadequate sanitation infrastructure on their health.

4.1 *Socio-economic challenges that confronts informal settlements residents*

Observations at Four informal settlements in Johannesburg revealed socioeconomic challenges such as poverty, unemployment, a lack of land tenure security, limited access to services, health risks, social exclusion, stigma, and gender inequality. Residents, mainly unemployed and low-income earners, struggle to afford adequate sanitation infrastructure due to limited financial resources. High levels of unemployment and underemployment exacerbate their financial instability, making it difficult to invest in sanitation improvements (Corburn and Sverdlik 2019). The prevalent toilets are chemical and mobile, and residents lack formal land tenure rights, leading to precarious living conditions. Inadequate waste management contributes to unsanitary conditions and environmental pollution, especially for vulnerable groups like children and the elderly (Tsekane 2020). Social exclusion and stigma further compound these (Nkere 2014).

4.2 *Discussions*

The study examines the socio-economic challenges faced by residents of informal settlements in Johannesburg, highlighting the negative impact of inadequate sanitation infrastructure on their health and well-being. It emphasizes the need for education and empowerment to address issues like overcrowding, informal waste management, a lack of planning, and social stigma (Chersich *et al.* 2018). The study highlights the interconnected relationship between sanitation infrastructure challenges, socio-economic impacts, and negative effects on health and well-being (World Bank 2020). Improving sanitation infrastructure through education and empowerment can lead to positive outcomes, fostering social integration, tranquillity, and overall health and well-being.

5 THEORETICAL FRAMEWORK UNDERPINNING THIS STUDY EDUCATION AND EMPOWERMENT

The study investigates the need for education and empowerment in addressing sanitation infrastructure issues in informal settlements using five theoretical frameworks: The Health Belief Model (HBM), Social Cognitive Theory (SCT), Community-Based Participatory Research (CBPR), Capability Approach, and Environmental Justice Framework. These frameworks provide a comprehensive understanding of the behavioural and structural dimensions of sanitation infrastructure challenges. However, two frameworks specifically address the issue of education and empowerment in Johannesburg's informal settlements, highlighting the need for a comprehensive approach to addressing sanitation infrastructure challenges.

5.1 *Health Belief Model (HBM)*

Health Belief Model (HBM): The Health Belief Model (HBM) highlights the importance of individual beliefs and perceptions in shaping health-related behaviours. It suggests that individuals are more likely to take action to prevent health problems if they perceive themselves as vulnerable, understand the severity of consequences, believe in the effectiveness of preventive actions, and perceive few barriers to taking action (Oriyi and Ogwey-Ndisika 2023). In the context of sanitation in informal settlements, education can play a crucial role in raising awareness about health risks associated with poor sanitation, informing residents about the links between inadequate sanitation and diseases like cholera and diarrhoea, and motivating behaviour change. Education can improve sanitation practices by influencing perceptions and motivating behaviour change. Empowerment involves equipping residents with knowledge and skills to advocate for better facilities and participate in community-driven initiatives (Anuar *et al.* 2020).

5.2 *Social Cognitive Theory (SCT)*

SCT emphasizes the role of observational learning, social influences, and self-efficacy in shaping behaviour. It suggests that people learn by observing others and assessing their actions, and self-efficacy significantly influences their engagement in certain behaviours (Govindaraju 2021). In the context of sanitation in informal settlements, education programs can promote behaviour change by demonstrating correct sanitation practices through role models. Empowerment within SCT involves building confidence and skills among residents to engage in collective actions promoting better sanitation infrastructure (Thojampa and Samkhaowkhom 2019). These theoretical frameworks provide a method to understand and tackle sanitation issues in informal settlements, aiming to instil residents with the confidence and skills to participate in initiatives aimed at enhancing sanitation in Johannesburg.

6 EMPOWERING RESIDENTS FOR SUSTAINABLE SOLUTIONS

To address sanitation issues in Johannesburg's informal settlements, it is crucial to build local capacity, empower residents, community-based organizations, and institutions, involve them in decision-making, provide training, and foster local leadership, which are essential for addressing sanitation challenges (Ajith *et al.* 2022; Beer *et al.* 2019).

6.1 *Empowering women and youth: Proposed solution*

6.1.1 *Community-Led Total Sanitation (CLTS) initiatives*

Description: CLTS is an approach that empowers communities to eliminate open defecation by facilitating behavioural change and encouraging the construction of local sanitation facilities (Wasonga *et al.* 2023).

Implementation:

- Training and Workshops: Conduct workshops to educate women and youth on the importance of sanitation and hygiene.
- Community Mapping: Involve youth in mapping areas lacking sanitation facilities and identifying suitable locations for new installations.
- Peer Educators: Train women and youth as peer educators to promote hygiene practices within their communities.

Case Study: The CLTS approach in Kenya improved sanitation in rural areas by empowering local women and youth, leading to communities achieving Open Defecation Free (ODF) status through collective action and local leadership (Chikozho *et al.* 2019; Okumu *et al.* 2022).

6.1.2 *Women-led sanitation enterprises*

Description: Establish women-led enterprises focused on providing sanitation services, such as the construction and maintenance of toilets, waste collection, and the production of sanitation products (e.g., reusable sanitary pads) (Njeru 2021; Panchol 2023).

Implementation:

- Microfinance and Grants: Provide microfinance options and grants to women entrepreneurs to start sanitation businesses.
- Skill Development: Offer training programs on business management, sanitation technology, and construction skills.
- Market Linkages: Create linkages with local government and NGOs to ensure market access and sustainability.

Case Study: In Uganda, women-led sanitation enterprises have successfully improved access to sanitation facilities and generated income for women, enhancing their economic independence and community status (Akaezuwa *et al.* 2020).

6.1.3 *Youth innovation hubs*

Description: Establish innovation hubs where youth can develop and implement creative sanitation solutions using modern technology and sustainable practices (Sahni *et al.* 2023).

Implementation:

- Hackathons and Competitions: Organize hackathons and competitions to encourage youth to create innovative sanitation solutions.
- Mentorship Programs: Pair young innovators with mentors from the sanitation sector to refine and scale their ideas.
- Incubation Support: Provide incubation support, including funding, technical assistance, and business development services.

Case Study: The "Swachh Bharat Hackathon" in India involved thousands of young people in developing sanitation solutions, leading to the creation of several successful start-ups focusing on sustainable sanitation technologies (Sandesh 2023; Singh *et al.* 2023).

6.1.4 *Participatory planning and decision-making*

Description: Involve women and youth in the planning and decision-making processes for sanitation infrastructure projects to ensure their needs and perspectives are considered (Caruso *et al.* 2022; Geekiyanga *et al.* 2020; Szetey *et al.* 2021).

Implementation:

- Community Committees: Form community committees with significant representation of women and youth to oversee sanitation projects.
- Consultative Meetings: Hold regular consultative meetings to gather input from women and youth on sanitation issues and solutions.
- Feedback Mechanisms: Establish feedback mechanisms, such as suggestion boxes and mobile apps, to continuously capture the views and experiences of women and youth.

Case Study: Participatory planning involving women and men in urban slum areas in Brazil has resulted in more effective and inclusive sanitation projects, enhancing community health and wellbeing (Ciccotti *et al.* 2020, Coy *et al.* 2019).

The study suggests that empowering women and youth in Johannesburg's informal settlements through community-led initiatives, women-led enterprises, youth innovation hubs, and participatory planning can significantly address sanitation infrastructure challenges. These solutions, based on local knowledge and successful examples, are practical, feasible, and tailored to the local context, ensuring sustainability - a roadmap for meaningful improvements in sanitation infrastructure.

7 SUMMARY AND CONCLUSION

The research highlights the health, social, and economic risks faced by residents in informal settlements in Johannesburg due to inadequate access to clean water, basic sanitation infrastructure, and proper hygiene practices. These issues contribute to waterborne diseases, compromise dignity and well-being, and perpetuate socio-economic inequalities (Adigun 2018). Successful interventions involve community participation, behaviour change, multi-stakeholder collaboration, tailored approaches, sustainable operation, and ongoing monitoring and evaluation. Strategies for implementing sustainable solutions include empowering women and youth, building local capacity, and collaborating with NGOs and government agencies. Upgrading sanitation infrastructure, improving waste management systems, and implementing innovative approaches can lead to lasting change in informal settlements. A comprehensive approach that includes residents' education, investment in infrastructure development, education, capacity building, and behaviour change interventions is essential for success (Nassar and Elsayed 2018). Education and empowerment can improve sanitation infrastructure in Johannesburg, leading to improved health, well-being, and sustainable communities. Future research should examine the impact of vandalism on existing infrastructure during protests and complaints by residents.

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Evaluating the nutrient suitability of digestate derived from anaerobic digestion of black soldier fly larvae fecal sludge composting residues as manure

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ABSTRACT: Adopting sustainable agricultural practices including production of organic manure is a critical step towards sustainable future for agriculture. This study explored anaerobic digestion (AD) as a post-treatment method for black soldier fly larvae (BSFL) residues for nutrients enhancement and production of mature and stable organic manure. The BSFL residues were subjected to AD, measuring nitrogen (N), phosphorus (P) and potassium (K) levels using Kjeldah and Spectrophotometric methods. Results indicated increase in N, P, and K with concentrations rising from 4.16% to 4.5%, 2.36% to 2.8%, and 0.029% to 0.03%, respectively. Statistical analysis revealed no significant nutrient variation between the control and anaerobic digestate, with p-values 0.807 for N, 0.051 for P, and 0.980 for K. Despite this, N and P met Malawi fertilizer quality standards, but K did not. The findings show that AD can stabilize N and P in BSFL residues while suggesting further investigation for K levels.

Keywords: Sustainable agriculture, organic manure, black soldier fly larvae, nutrient enhancement, fecal sludge management

1 INTRODUCTION

In contemporary agriculture, the quest for sustainable and environmentally friendly practices is even more critical (FAO 2014). Organic manure, rich in essential nutrients such as Nitrogen, Phosphorus, and Potassium, play a central role in ensuring robust crop growth and yield (Hariyadi 2022; Umami 2019). A number of ongoing studies have stated

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the crucial role of nutrients in maintaining crop yields. For instance, long term agricultural research conducted by Lollato *et al.*, (2019) in Oklahoma reported that wheat yields would decrease by 40% in the absence of regular conditions of nitrogen and phosphorus. Similarly, a survey focusing on United States crop production has revealed that the absence of nitrogen fertilizer could result in 40% reduction in average corn yields (Krasilnikov and Taboada 2022). Additionally, a study conducted in Western Ethiopia reported between 31 to 72% higher maize grain yield with nitrogen fertilization compared to control (Abera *et al.* 2017).

The nutrients stated in the ongoing studies are primarily from mineral-based fertilizers, which come with a set of environmental and economic challenges. Their production involve release of toxic chemicals and gases like ammonium and carbon dioxide (Chandini *et al.* 2019). When these byproducts generated during manufacturing of chemical fertilizers are discharged in water bodies result in eutrophication effect. Eutrophication occurs when water bodies are enriched with excess nutrients, causing excessive plant and algae growth (Chandini *et al.* 2019). This overgrowth harms the aquatic lives and result in water quality problems (Chandini *et al.* 2019). Also, the use of this type of fertilizer can result in the leaching of chemicals into the soil due to rainfall, which further contributes to environmental problems (Khan *et al.* 2018). In addition, the application of these fertilizers releases greenhouse gases into the atmosphere, contributing to climate change and global warming (Walling andVaneeckhaute 2020). Additionally, the chemical fertilizers are often expensive, especially for small-scale farmers, particularly in developing countries. Research conducted in Malawi, for instance, revealed that small-scale farmers could not afford to purchase these fertilizers, hindering their ability to maintain crop productivity (Phiri 2016). A similar case was reported by Benson *et al.* (2013) revealing the higher costs of fertilizer in Mozambique compared to costs in other coastal countries in Africa that is not affordable to smallholder farmers. This situation emphasizes a growing need for more sustainable and affordable sources of essential nutrients like N, P and K. The solution lies in the adoption of organic manure, which farmers can often produce themselves. Various low cost methods, such as anaerobic digestion, composting and black soldier fly larvae digestion, offer promising alternatives for producing organic fertilizers (Di Costanzo *et al.* 2021).

The use of black soldier fly larvae has been at the forefront of innovative solutions in organic waste management (Siddiqui *et al.* 2022; Singh and Kumari 2019). Research has indicated that these larvae can efficiently digest organic waste materials, including fecal sludge, within a relatively short period of time ranging from 14 to 16 days (Dortmans *et al.* 2021). However, the residues remaining after digestion process has been found to lack the stability and maturity required for direct use as manure. When applied to farms, it falls short of delivering the expected high yields, primarily due to its immature state. This is evident from the previous studies conducted, which examined the effectiveness of BSFL residues as organic manure and reported poor plant growth and low yields than expected (Kebli and Sinaj 2017; Menino *et al.* 2022). According to Dortmans *et al.* (2017), poor plant growth could be related to immaturity of the waste residue produced from the BSF treatment process, which led to inadequate oxygen and nitrogen in the soil. For this reason, additional method for post-treatment of BSFL residues is needed before using them as manure.

There are various methods that can be used in post-treatment of BSFL residues including composting, anaerobic digestion, vermicomposting and pyrolysis (Márquez *et al.* 2024). Anaerobic digestion is the most beneficial method because it not only produces digestate for fertilization but also, biogas as a renewable energy source (Aworanti *et al.* 2023). AD is a process that naturally occur, requiring no energy input and not causing any pollution to the environment (Aworanti *et al.* 2023). This study therefore, explored AD as an additional treatment method for BSFL residues. This method involves subjecting the residues from BSFL composting to anaerobic conditions, with the hypothesis that it may lead to the maturation and stabilization of these residues, rendering them suitable for use as organic manure. This research was motivated by a need to contribute towards efforts of managing environmental waste while recycling nutrients that could be used in agriculture. Most of previous studies have primarily focused on investigating anaerobic digestion of BSFL residues for biogas production Wedwitschka *et al.* 2023; Bulak *et al.* 2019; Win *et al.* 2018). This research add further knowledge by investigating enhancement of nutrient content and the stabilization of the BSFL residues for use as a high-quality organic fertilizer. The study addresses the existing research gap regarding the quality and suitability of BSFL residues as fertilizer by investigating the potential of AD to increase nitrogen and phosphorus levels and produce a stable and mature digestate. The approach not only provides empirical evidence on nutrient enhancement but also demonstrates how AD can transform BSFL fecal sludge composting residues into a nutrient-rich, stable organic manure. The dual focus on improving nutrient profile and stability of the residues offer comprehensive and effective utilization of BSFL residues in sustainable agricultural practices and in waste management strategies.

2 MATERIALS AND METHODS

2.1 *Composting of fecal sludge with BSF larvae*

Fecal sludge was used as the feed for BSFL. The fecal sludge was collected from unlined pit latrines in Ndirande Township of Blantyre City in Malawi. The sludge was collected from unlined pit latrines because it's a common and widely used sanitation method in Blantyre. It was collected from the surface to 1.5 m depth. Collection involved scooping sludge at the top and pumping using gulper to 1.5 m depths. Sludge at the surface to 1.5 m depth was not stabilized, which made it suitable for BSFL rearing. Collecting sludge further than 1.5 m was not possible because gulper could not pump beyond such depth. Composting experiment was performed at laboratory scale with the experiment facility set at the rooftop of School of Engineering building at Malawi University of Business and Applied Sciences (MUBAS) in Blantyre, Malawi. The experiment involved control and treatment containers. In a control container, fecal sludge was fed without addition of BSFL and left for composting. The sludge was added every day and composted with the rates and environmental conditions similar to treatment containers.

In a treatment container, BSFL of 10 days old were used for digestion of fecal sludge. The BSFL were fed incrementally at the rate of 50 mg of fecal sludge per larvae per day, for 13 days as informed from the literature (Tokwaro *et al.* 2023). Fecal sludge was maintained at 50 mm depth in the containers. Rearing was performed at controlled moisture content of 65%, uncontrolled humidity level and temperature of 64-68% and 25-30 ^{0}C, respectively. The sludge depth in the containers and conditions for BSF rearing, (temperature, moisture content, feeding rate and rearing period) were informed by the previous studies (Banks *et al.* 2014; Tokwaro *et al.* 2023).

2.2 *Anaerobic digestion of BSFL residues: Experimental design*

Anaerobic digestion experiment was conducted at laboratory scale. In this experiment, the BSFL residues were used as a feedstock. The anaerobic digestion was conducted for further treatment of fecal sludge BSFL residues to enhance nutrients recovery and stabilization. The experiment involved both control and treatment, for a control BSFL residues were fed in a container without anaerobic conditions. Container was left uncovered, mixing was performed manually on daily basis and operated in conditions similar to the anaerobic digester. For a treatment, the BSFL residues were fed in anaerobic digester and operated as explanations in the subsequent sections. The digestion process was performed under dry conditions where, total solid (TS) concentration was between 15% to 25% TS. In this study dry digestion of 1:4 solid-water ratio was used as informed by the previous studies (Li 2015;

Voskamp 2017). The study further used a hydraulic retention time (HRT) of 20 days, as informed by literature (Banks 2007) that a typical value for hydraulic retention time for the digestion of fecal sludge is 20 days. HRT is the time that the feed stocks spend inside the digester. The study incorporated a batch type of feeding, where, the digester was only fed at the beginning of the experiment then sealed tightly and left sealed for the entire duration of the anaerobic digestion. Batch-feeding method because of its low labor requirements and simple digester system design.

The BSFL residues inside the digester was manually agitated every after 24 hours while sealed. Agitation helps to ensure homogeneity of the material in terms of temperature and pH. It also reduces the formation of sediments on the bottom of the digester hence ensure uniform solid concentration for the better performance of the anaerobic bacteria. During anaerobic digestion, the temperature was not controlled. The digestion was performed under room temperature conditions ranging from 19 to 27 ^{0}C and temperature inside the digester ranged from 25 to 35 ^{0}C which was within mesophilic temperature range. The increase in temperature inside the digester was an indication that there was microbial activity that was taking place. Before feeding the digester, the feed material, BSFL fecal sludge residues were characterized in terms of its nutrient content such as phosphorus, nitrogen and potassium. The same parameters were analyzed for control and the anaerobic digestate after 20 days HRT.

Four sets of samples were collected, that is for raw fecal sludge, BSFL residues, control and the digestate. Each set of samples was collected in triplicate to ensure accuracy and reliability of results. To preserve the integrity of the collected samples, they were stored at a controlled temperature of 4 ^{0}C until ready for analysis. This cautious storage minimized the risk of degradation or alterations in the samples' characteristics before they were studied. Two experimental runs were conducted to ensure reproducibility, adhering to standard scientific practice for reliable and consistent results. All the collected samples were analyzed for N, P and K. The parameters were analyzed using the laboratory standard methods. Nitrogen was analyzed using a Kjeldahl Method in Laboratory Methods of Soil and Plant Analysis (Okalebo *et al.* 1993). Phosphorus and potassium were determined using Spectrophotometric Method as presented by the Association of Official Analytical Chemists (AOAC) of United States of America in its 17th Edition publication on Official Methods of Analysis. An independent samples t-test was performed using Statistical Package for the Social Sciences (SPSS) at 95% confidence level to compare mean nutrients levels in a control and anaerobic digestate. The significance level, alpha used was .05 for t-test. All the obtained data was presented in tabular form using Microsoft Excel.

2.3 *Solid fertilizer quality standards*

The results for nutrients were analyzed for suitability as a fertilizer against the existing secondary data. The percent values for nitrogen, phosphorus and potassium were compared against the standards outlined in the Fertilizer Act of 2003 of Government of Republic of Malawi as presented in Table 1.

Table 1. Fertilizer quality standards.

S/N	Test Parameters	Unit	Quality Standards
1	Nitrogen	%	>1
2	Phosphorus	%	>1
3	Potassium	%	>1

Source: Ministry of Agriculture of the Republic of Malawi (2003).

3 RESULTS

3.1 *Nutrients concentration in raw fecal sludge*

Raw fecal sludge initially composted with BSFL contained a nitrogen concentration of 30.3%, phosphorus 17.8% and potassium 0.025%. These concentrations have been presented in Table 2 expressed in mg/kg.

Table 2. Mean nutrients concentration in raw fecal sludge.

Nutrients	Mean concentration (mg/kg)
Nitrogen	30333.33
Phosphorus	17823.33
Potassium	253.17

3.2 *Nitrogen*

The results presented in the Table 3 consist of mean concentration of nitrogen in black soldier fly larvae (BSFL) residues, control and the concentrations in the digestate after anaerobic treatment. Mean nitrogen concentration in a BSFL residues was 41611.11 mg/kg. The concentration in a control increased to 42350 mg/kg and 45888.89 mg/kg in anaerobic digestate. The percentage increase of 1.74 % and 9.32% was observed in a control and treatment with anaerobic digestion, respectively. T-test results revealed that nitrogen concentration in anaerobic digestate did not differ from the control treatment ($t\ (10) = 0.827$, $p = .427$).

Table 3. Mean values of nitrogen (N) in the BSFL residues, control and anaerobic digestate.

	Mean nitrogen (mg/kg)		
Treatment	Feedstock (BSFL residues)	Digestate	Change in concentration (%)
AD	41611.11	45888.89	9.32
Control	41611.11	42350.00	1.74

3.3 *Phosphorus*

As shown in Table 4, before anaerobic digestion of BSFL residues concentration of phosphorus was 23638.81 mg/kg. After treatment with anaerobic digestion the mean concentration increased to 27583.54 mg/kg in a digestate and 24576.96 mg/kg in the control. The phosphorus concentration in a control increased by 3.82% and 14.3% in anaerobic digestate. Statistical test results, ($t\ (10) = 1.875$, $p = .09$) show that there was no significant difference between feedstock and anaerobic digestate.

Table 4. Mean values of phosphorus (P) in the BSFL residues, control and anaerobic digestate.

	Mean phosphorus (mg/kg)		
Treatment	Feedstock (BSFL residues)	Digestate	Change in concentration (%)
AD	23638.81	27583.54	14.30
Control	23638.81	24576.96	3.82

3.5 *Potassium*

Potassium mean concentration in a BSFL residues was 293.17 mg/kg, 293.94 mg/kg in a control and 296.97 mg/kg in anaerobic digestate. The concentration increased by 0.26% in a control and 1.28% in anaerobic digestate as shown in Table 5. The conducted statistical test, independent sample t-test ($t(10) = 0.027$, $p = .979$) suggests that the differences in mean concentrations between control and anaerobic digestate are not significant.

Table 5. Mean values of potassium in BSFL residues, control and anaerobic digestate.

Treatment	Mean potassium (mg/kg)		Change in concentration (%)
	Feedstock (BSFL residues)	Digestate	
AD	293.17	296.97	1.28
Control	293.17	293.94	0.26

4 DISCUSSION

4.1 *Nitrogen*

An increase of 9.32% in nitrogen content indicates that anaerobic digestion process efficiently broke down organic compounds, like proteins, that were in the residues of BSFL. The breakdown releases nitrogen in a soluble form such as ammonium, which enriches the digested material with this vital nutrient (nitrogen). These findings align with principles of anaerobic digestion, that microorganisms decompose organic matter in the absence of oxygen resulting in the release of ammonium and nitrate. The study found that anaerobic digestion of BSFL residues led to higher increase in nitrogen concentration compared to the control treatment (1.74%). The increase in nitrogen concentration control treatment was probably influenced by natural bacterial activities. The reported p value of .427 indicates that there is no significant difference in nitrogen concentration changes between the experiment (anaerobic digestion) and the control treatments. Statistically, this means that the observed changes could potentially be due to random variability rather than true effect of anaerobic digestion. However, it is important to note that p values alone do not determine practical significance of a result. In this case, where p value is relatively high, the percent change in concentration and the biological mechanism behind the effect of anaerobic digestion process on nitrogen was considered; as well as the trend similarity with the previous literature. For instance, the observed change in nitrogen levels is in line with the previous research by Massé *et al.* (2007) who reported an increase in nitrogen concentration from 6.7% to 9.79% after anaerobic digestion. Another study by Möller and Müller (2012) also reported 45 -80% increase in concentration of nitrogen in anaerobically digested waste materials aimed for production of biogas. The percent increase in nitrogen in the current study was much lower than in the study by Möller and Müller (2012), this difference could have been influenced by the presence of less organic nitrogen compounds in the feedstock materials. The possible reason for less nitrogen compounds in the feedstock could be the pretreatment of fecal sludge conducted using the BSFL digestion that has already mineralized organic bound nitrogen into readily available form for plants. On the other hand, the study by Soyingbe *et al.* (2019) reported lower nitrogen (%) concentration (0.36 ± 0.02) in digestate from co-digestion of fecal sludge and cow intestinal compared to the current study. The high concentration in this study could be due to the nature of the original feedstock, fecal sludge only which is known to containing high nutrient content (Jothinathan and Singh 2023; Zhang *et al.* 2023). This result disagreed with the results reported by Smith *et al.* (2013), who observed decrease in nitrogen concentration in anaerobic digestion of livestock manure. The increase in nitrogen content by 9.32% is within the expected range for anaerobic digestion processes and its practically significant in terms of agricultural application. While the literature reports a wide range of increases, from as low as 6.7% to as high as 80% (Luis *et al.* 2019), the variation is largely dependent on the composition of the feedstock and the efficiency of the digestion process. Compared to other waste treatment methods, such as composting or aerobic digestion, anaerobic digestion tends to retain more nitrogen, making the resulting digestate a richer fertilizer (Macura *et al.* 2019). The increase in nitrogen concentration is an indication that anaerobic digestion of BSFL residues can produce nutrient-rich organic manure, enhancing soil fertility and crop yields. The use of this final digestate in agriculture could replace an expensive synthetic nitrogen fertilizer.

4.2 *Phosphorus*

The observed percent increase (14.3%) in phosphorus concentration could be due to biological processes inside the digester where microorganism breakdown the organic matter and hydrolyze complex organic phosphorus compounds into soluble forms, such as orthophosphate that are readily available for plant uptake. As a result, soluble form of phosphorus was released into the digestate, leading to overall increase of its concentrations. Comparing the two treatment conditions, anaerobic digestion showed higher increase in phosphorus concentration, 14.3% than control, 3.82%. The increase in concentration observed was likely not from random chances but from anaerobic digestion considering change in concentration and biological mechanisms associated with phosphorus transformation by bacteria during anaerobic digestion. The observed increase in phosphorus concentration in this study agrees with findings from previous study by De Graaff *et al.* (2011) where the researchers reported 14.13% increase in phosphorus concentration after anaerobic digestion of black water. The obtained results in this study disagreed with the results by Smith *et al.* (2013) after anaerobic digestion of livestock manure, who observed decrease in phosphorus concentration in the digestate. This result also disagreed with the findings by Schievano *et al.* (2011) who reported a loss of phosphorus (2-9%) during anaerobic digestion. One possible reason for the difference (loss in phosphorus) could be the partial retention of phosphorus in the digesters due to sorption on small particle surfaces, as reported by Massé *et al.* (2007). Massé *et al.* (2007), on the other hand, observed an increase of phosphorus content after anaerobic digestion, similar to the current study. In this case, the influent had lower phosphorus content (1.7%) and the effluent increased to 3.42%, representing a 50% increase. The other study by Soyingbe *et al.* (2019) reported lower concentration of phosphorus, % (0.15 ± 0.1) in anaerobically digested mixture of fecal sludge and organic waste. In general, possible reasons for differences in phosphorus concentration in these studies could be the variations in feedstock composition among the studies and the differences in organic and phosphorus sources in the feedstocks. These results align with the concept that anaerobic digestion can lead to an increase in phosphorus concentration after the decomposition of complex organic compounds. In addition, the 14.3% increase in phosphorus concentration is consistent with increases reported in the literature, which can range from 14.13% to 50% after anaerobic digestion (Otieno *et al.* 2023). This increase is favorable and the technique can be used in agricultural practice. The higher phosphorus concentration indicates that anaerobic digestion can raise the phosphorus content of BSFL residues, resulting in the production of an excellent organic fertilizer. As a sustainable substitute for synthetic phosphorus fertilizers, this can increase agricultural yields and soil fertility.

4.3 *Potassium*

The observed increase in potassium concentration (1.28% increase) in the anaerobic digestion treatment group suggested that the digestion process has potential to release and mobilize potassium from BSFL residues. Anaerobic digestion process typically breaks down organic matter; release of potassium could be attributed to the breakdown of organic compounds in the residues. This finding aligns with the broader understanding of anaerobic digestion as a bio-process capable of solubilizing and mineralizing organic matter, liberating nutrients for potential reuse. The relatively small increase (0.26%) in potassium concentration observed in the control group, on the other hand, could be attributed to natural decomposition processes. Some natural decomposition can occur even without the anaerobic digestion treatment, and this could contribute to increase in potassium concentration over time.

The statistical results, p value = 0.0979 do not necessarily invalidate the biological significance of the findings, keeping in mind that the statistical significance was influenced by sample size and variability, and a larger sample size might have resulted in a lower p value. Literature suggests that a larger sample size of at least 30 runs would increase the power of a statistical test, which is the probability that the test will correctly reject a false null hypothesis (Columb and Atkinson 2016). However, lab-based studies are limited to have few runs, less than 30 that made it difficult detecting true effect of anaerobic digestion. A p value close to .05 suggests a trend or potential effect that could become significant with more data. Potassium concentration obtained was lower than the value reported in a study carried out by Soyingbe *et al.* (2019), who observed 0.3 ± 0.12 potassium (%) in digestate of the mixture of fecal sludge and cow dung. The low value could be attributed to low availability of potassium organic compounds in the feedstock since the review study by Möller (2012) reported that the nutrients concentration in the digestate depend on the presence of nutrients in the initial feedstock. The results obtained in this research were consistent with the one obtained by Massé *et al.* (2007) on their study about the fate of crop nutrients during anaerobic digestion, where they observed an increase of potassium concentration from 2.7% to 3.24%. However, this results disagreed with the findings obtained by Smith *et al.* (2013) in their study on anaerobic digestion of livestock manure, where they observed decrease in potassium concentration.

The 1.28% increase in potassium concentration observed underscores the potential of anaerobic digestate as a nutrient source or soil conditioner. The modest increase in potassium concentration demonstrates the efficacy of anaerobic digestion in enhancing soil fertility and supporting sustainable agricultural practices. However, it is important to note that the potassium levels are still below what is required for high-quality fertilizer. This suggests that while the anaerobic digestion process is promising, its practical viability may be limited without further optimization. It is necessary to consider that the lower-than-expected increase in potassium may not necessarily be a shortcoming of the anaerobic digestion process. Instead, it could be attributed to the inherently low potassium concentration in the original feedstock, which is fecal sludge (Jothinathan *et al.* 2023). Fecal sludge characteristics can vary significantly based on factors such as the type of sanitation system, the diet of the population, and the storage conditions of the sludge (Nicholas *et al.* 2023). While the potassium concentration increased only slightly, the anaerobic digestion process could still improve soil fertility. To create a more balanced and nutrient-rich organic fertilizer, future study should concentrate on improving the anaerobic digestion conditions and investigating feedstocks with a greater potassium content. Implementing this technique rather than artificial fertilizers, agricultural output and soil health may be enhanced, providing a sustainable substitute. This approach could lead to improved soil health and agricultural productivity, providing a sustainable alternative to chemical fertilizers.

4.4 *Comparison of nutrients concentration in anaerobic digestate with fertilizer regulatory standards*

In Table 6, respective values of nitrogen and phosphorus lie within provided range of quality standards while, the potassium level, 0.03% was found to be significantly below the standards. This could be attributed by the low potassium concentration in the original feed.

Table 6. Digestate test results.

S/N	Test Parameters	Unit	Quality Standards	Result	Note
1	Nitrogen	%	>1	4.5	Meets Quality Standards
2	Phosphorus	%	>1	2.8	Meets Quality Standards
3	Potassium	%	>1	0.03	Does not meet Quality Standards

Source: Laboratory results 2023.

5 CONCLUSION

The utilization of anaerobic digestion as an additional method in treatment of BSFL fecal sludge digestion presents promising results for enhancing nutrient levels. The study revealed an increase in nitrogen and phosphorus concentrations by 9.32% and 14.30%, respectively, meeting the fertilizer quality standards set by the Republic of Malawi. There was no significant increase in potassium content, falling below quality standards. This study therefore, highlights the potential of anaerobic digestion in improving nutrient levels of residues derived from BSF technology. The findings suggest that integrating anaerobic digestion with BSF treatment can lead to the production of higher quality organic fertilizers, supporting food security and improving waste management strategies. Implementing this combined treatment method could significantly enhance soil fertility, reduce environmental pollution and contribute to public health improvements in areas lacking adequate sanitation infrastructure. However, further investigations are needed, particularly concerning the levels of heavy metals, micronutrients and pathogen safety for manure handlers.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Planning for quality and sustainable infrastructure post-apartheid South Africa: Insights from Cosmo City Extension 6

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ABSTRACT: This paper explores the planning strategies employed in the development of quality and sustainable sanitation infrastructure in post-apartheid South Africa. Despite notable strides in addressing the historical imbalances perpetrated by the apartheid regime, the provision of inclusive, reliable, and sustainable sanitation infrastructure remains a critical concern. The study employed a qualitative method. Qualitative interviews, observations, policy and planning analysis, and a review of the literature were all done. The findings highlighted the complexity of planning for quality and sustainable sanitation infrastructure, exposing a range of issues that are interconnected such as limited financing, inadequate institutional capacity, and political will. These issues have an impact on social well-being, the environment, health, and implementation. The study contributed to various lessons, such as; the impact of community engagement and participation in decision-making processes in fostering project ownership, acceptance, and sustainable objectives and success.

Keywords: Sustainable development, Planning, Infrastructure, Resiliency, Sanitation

1 INTRODUCTION

The transition of South Africa from the apartheid regime to a new dispensation perceived as a democratic society heralded a new era of promises and aspirations, especially in the realm of urban planning, urban development, and infrastructure provision. The dismantling of institutionalised segregation and oppression brought forth an imperative to rectify historical injustices by addressing the glaring disparities in accessing essential services such as adequate housing, sanitation, and infrastructure settlements. Post-apartheid, South Africa has made significant strides in addressing these challenges which were mainly through segregationist policies. One key area that has garnered attention is the provision of sanitation infrastructure to previously disadvantaged communities. Hence the quest to critically analyse the strategies used to ensure quality and sustainable infrastructure, particularly regarding sanitation, emerged as a critical focal point in the urban planning discourse of post-apartheid South Africa.

Infrastructure development has been a crucial component of any nation's growth and serves as a testament to its progress, socio-economic development, and overall well-being of communities (Ekeocha et al. 2021). Investing in sustainable infrastructure development improves public health outcomes, reduces environmental degradation, and promotes economic development. Therefore, this paper presents the conceptual framework that sheds light on the challenges and issues faced by the South African government and local governments in providing adequate, quality, and sustainable sanitation infrastructure for its communities, particularly in the post-apartheid era. The paper briefly discusses the importance of sustainable infrastructure development in promoting the health and well-being of communities. The paper then discusses the research methodology used for the study, presents

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the results, summarises the findings, and suggests future steps to guarantee high-quality, long-lasting infrastructure that will improve the community's resiliency, well-being, and dignity for all.

2 CONCEPTUAL FRAMEWORK

Sanitation is interlinked with the environment, public health, economy, and human dignity (World Health Organization 2023). According to Bazaanah (2023), poor sanitation prevents a significant portion of the quality of life linked with dignity, health, access to clean water, and healthy ecosystems. Silveti and Andersson (2019) asserted that cities fail to provide a quality and sustainable sanitation system that meets and satisfies the needs and demands of the population. According to Silveti and Anderson, the biggest obstacles to cities, especially those in the Global South, in providing quality and sustainable infrastructure are financing capacity, lack of resources, mismanagement of available resources, and lack of political will. Such provision is crucial in addressing basic human needs, but it also plays a critical role in promoting public health and reducing inequalities, child deaths, and hunger (McFarlane 2019).

Therefore, this study in broader terms developed the analytic framework of planning approaches in Cosmo City and established the reason for the deterioration of the sanitation infrastructure. According to Mitra et al. (2022), sanitation is a universal need, and lack of it threatens universal rights for the people in the community.

2.1 *An overview of challenges*

With a fast-growing urban population, South Africa is one of the most urbanized nations in Africa. According to the World Bank (2022), 68.33% of South Africans moved from rural to urban areas in 2022. This migration resulted in urbanisation-related challenges like urban poverty, housing affordability issues, rising inequality, and environmental degradation (Zhang 2016). According to Rogerson et al. (2017), urbanisation takes place on a different scale in South Africa and it reflects a state of crisis that manifests in the growth of informal urban life, which affects the infrastructure and the functionality of the cities (Panell and Pieterse 2014).

An African challenge has always been how to provide sanitation services that are adequate for quality of life and people's dignity (Bazaana 2023). There is a need to critically evaluate and change how sanitation planning and service provision are approached. To effectively unpack this, there is a need to analyse the contributory variables required to understand the sanitation shortcomings in Africa. These elements include inadequate institutional frameworks, inefficient monitoring and evaluation mechanisms, ineffective urban planning and land use, as well as lack of finances and capital (Kaamah et al. 2023).

Urban infrastructure is a perennial problem for African cities that requires an urban planning response, according to Gaisie and Cobbinah (2023). Cities such as Johannesburg, Gaborone, and Windhoek, are deeply affected by poverty, massive infrastructure backlogs, weak structural capacity, and a lack of financial muscle to develop, renew, or maintain the existing infrastructure (Garcia et al. 2022). As a result, this has created an African paradox of poor service delivery, and poor urban infrastructure due to poor urban governance

3 THEORETICAL OVERVIEW OF SANITATION INFRASTRUCTURE

3.1 *Community-led total sanitation infrastructure*

According to Tortajada (2020), poor sanitation infrastructure has adverse effects on the economy and it disproportionately affects the health and dignity of women (Khanna and

Das 2016). As a response, the community-led total sanitation approach was developed. The focus is on community upliftment and knowledge that affect behaviour change. The communities are encouraged to recognise the impact of poor sanitation practices and initiate collective action to foster sustainability.

3.2 *Social cognitive theory*

The theory was developed by Albert Bandura in the 1960s to emphasise the dynamics of interaction between people, who he identified as personal factors, their behaviour, and the environment. Social cognitive theory explores the influence of individual experience, actions, and environmental factors. According to Luszczynska and Schwarzer (2005), the social cognitive theory involves adoptive, initiation, and maintenance of behaviour for individuals and communities to emulate the practices that increase the adoption of innovative and effective sustainable infrastructure solutions. The social cognitive approach has a significant impact on how individuals, communities, and organisations approach and implement sustainable sanitation infrastructure.

3.3 *Behaviour change*

The emphasis is on the role of observational learning and modeling in shaping behaviour in which individuals and communities respond to infrastructural challenges.

3.4 *Self-efficacy*

The theory highlights the importance of self-efficacy, which is individual belief to plan, implement, and maintain sanitation infrastructure around them.

3.5 *Social support*

Social relationships and networks on individual behaviours and outcomes are very imperative. Through collaboration and cooperation among various stakeholders, that is, government agencies, non-governmental organisations, community members and private sectors, sustainable sanitation infrastructure projects can be successfully discharged. This can be through increased social support and collective action.

3.6 *Environmental influences*

Social cognitive theory underscores the role of environmental factors such as policies, regulations, and economic conditions in shaping individual behavious and decisions. Therefore, creating a conducive and enabling environment for quality and sustainable sanitation infrastructure, town planners, and policy makers can leverage this theory to address systemic barriers and promote the adoption of innovative and environmentally friendly sanitation infrastructure solutions.

In summary, the social cognitive theory provides undoubtedly valuable insights and mechanisms for planning for quality and sustainable sanitation infrastructure, especially in developing countries. It emphasises behavioral change, self-efficacy, social support, and environmental influences, that is, if these principles and strategies are effectively applied, stakeholders can work together to address the complexity of planning for sustainable infrastructure and build a more equitable and sustainable future for all citizens.

4 METHODOLOGY

The choice of Cosmo City was of fundamental interest as the community represented a typical radical departure from the inequalities and racial and segregation housing of pre-apartheid and it acted as a pilot project of the Republic of South Africa. Cosmo City represented an integrated social housing project and mixed land use that breathed hope, paradise and a dream come true for the poor and marginalised informal settlements of Itsoseng, Zevenfontein, and Riverbend.

Behind this choice was to generate data that is exploratory, analytical, and non-statistical (McNabb 2004:341). The perceptions of the residents of Cosmo City Extension 6 on the deteriorating infrastructure and ongoing sanitation infrastructural projects, were part of the reasons that made the researcher opt for a qualitative research method. Cresswell (2014) lamented that a qualitative approach emphasises the notions of the respondents, key ideas and objectives are explored, fresh insights (Gibbs 2007), new facts (Pandey and Pandey 2015), and detailed views of information that are not documented. The study used open-ended questionnaires and interviews were utilised to obtain the data. The questions that guided the study were:

(1) How does one explain Cosmo City, which is a fairly new community occupied in 2005–2010, but by 2023 the sanitation infrastructure is already suffocating and collapsing?
(2) Which approaches can be used to enhance the design and implementation of high-quality long-lasting sanitation infrastructure in Cosmo City Extension 6?

Through these questions, Cosmo City Extension 6, was seen as the microcosm of the broader issues facing South African cities and African cities as a whole. Neglect and underinvestment in infrastructure have contributed to the current dilapidated state of infrastructure. Moreover, in the wave of urbanisation, negative rather than positive impacts have been experienced reflecting the urgent need to redress the infrastructure challenges to accommodate the growing population.

The study also engaged snowballing sampling where the ward councillor helped to identify two members of the Ward Committee and these two members referred the researcher to more residents who were senior community leaders within Cosmo City. Given the qualitative nature of the study, thirty-one participants were involved, a sample size justified by Vasileiou in 2018. The participants comprised twenty-two residents who were interviewed on a face-to-face basis; six community leaders including the ward councilor and his committee members; two Municipal officials, who were interviewed telephonically; and a town planner from Urban Dynamics was interviewed via Teams. This sample size was motivated by the fact that the population of people living in Cosmo City Extension 6 was unknown; there was no statistical data or estimation available to guide the researcher to adopt other techniques provided by researchers such as Lincoln and Guba (1985) and Morse (1994). The target group of the initial residents or occupants of Cosmo City was critical in that the information collected was fully informative, first-hand, factually detailed, and nuanced based on lived experience from inception to date.

The research study arose from the context of planning for sustainability that promotes dignity, respect, and a healthier lifestyle. The problem statement critically pointed to the quality and sustainable sanitation infrastructure theme that emanated from the context of Sustainable Development Goals. Especially, goals that sought to eradicate poverty, good health and well-being, and sustainable cities and communities. The data collected in this study were analysed based on these themes, including the legislation, policies, and literature from published and unpublished literature and other documents.

5 FINDINGS

The study was area specific to Cosmo City Extension 6, situated in the North of Johannesburg. It is strategically located 12 km from Lanseria Airport. Cosmo City was initially a bare farmland partially owned by ABSA and politician-cum-farmer, Robert van Tonder. In 2005, Cosmo City was officially opened, after several court cases against the objections to the development. The wealthy property owners of the Jukskei Crocodile Catchment Area Forum objected, stating that the intended development would devalue their properties (Sowetan Live 2007). This was a clear indication of spatial racial segregation that still existed post-apartheid, which the City of Johannesburg, then the Northern Metropolitan Local Council, was fighting to eradicate.

Cosmo City has faced unending sanitation-related challenges since its inception, mainly due to infrastructural deterioration. Questions have been raised regarding the planning of such infrastructure and the quality and its sustainability, to be resilient to ever-growing challenges.

Interviews were conducted with the residents of Cosmo City who experience the challenges of sewer pipe bursting, uncollected solid waste, overflowing smelling wastewater, and poor drainage systems. Municipal officials, Private Developers, and Town planners were also interviewed to understand the shortcomings of these challenges and how they can be rectified to restore the dignity of the communities and ensure the sustainability of infrastructure.

5.1 *Objective 1. To establish the contributing factors that led to the collapse of the sanitation infrastructure in Cosmo City Extension 6*

The interviewee's responses reveal that the wave of urbanisation leading to overpopulation is the main cause. The sad part is that the Municipality is statistically unarmed and there is blame shifting. They point out that the national government is responsible for controlling and managing the population influx. This is solidified by the comments made by one of the Municipal officials, who postulated that "the Municipality has no jurisdiction in controlling or managing the borders. We wouldn't be experiencing such if the government could play its part. There are so many illegal foreign nationals that are unaccounted for, and that put much strain on the infrastructure." However, taking a closer look at Local Government: Municipal Systems Act 32 of 2000, municipalities are tasked with ensuring that all residents regardless of the population must provide "core principles, mechanisms, and processes that are necessary to enable them to move progressively towards the social and economic upliftment of all communities". Therefore, failure by the local municipalities to provide such a mechanism results in, what Nzimakwe (2020), described as enormous pressure exerted on local governments to provide adequate sanitation infrastructure to the communities. The United Nations Development Programme (2020), also concurred that population density due to urbanisation puts a strain on the sanitation infrastructure and services, resulting in inadequate waste management systems and the spread of waterborne diseases. The planning process lacked the cognisant of the urbanisation wave. It is clear the sole mandate was to provide housing to the available people, without widening the pool for the ever growing population.

According to one urban planner interviewed, the planning in Cosmo City was one of the high standards, He lamented that "all critical and salient aspects of planning were taken into consideration, that is the population; demography - people who were to occupy these houses; issues of place-making; and issues of accessibility." He further argued that the people who were the first beneficiaries had little or no knowledge of using toilets but training was provided for per household. He explained that Cosmo City was designed to be a world-class community, as a result, people who were taken from informal settlements were educated about sanitation and they were informed and trained about special zones to be created. Therefore, the urban planner blamed the Municipality for failing to maintain the high standard of infrastructure, they put in place when they "developed the world-class city of Cosmo City." However, for argument's sake, the statement by the urban planner leaves several loopholes and the question: if it was of high standard how is it deteriorating? Several practical theories were not applied when planning, given that the occupants of these houses were from informal settlements, low-income and middle-income backgrounds, and the need for behaviour change in these groups was never infused in planning. The community was not modeled and the behaviour changed. There was a general assumption that people wanted affordable housing with flushing toilets. The rest was outcasts.

According to the residents, the municipality is a passive participant in addressing the issues of sanitation infrastructure. Meetings are being held by the residents and the ward councilor, who give promises of positive actions, but they never materialize. The residents lament that all they saw was a project that was started at the edge of Cosmo City Extension 6. One respondent dismissed the project stating that "the project had negative effects on other infrastructure such as roads, storm-water drainage systems, and bridges. The municipality is failing to address these knock-on effects." This opens the criticism that the community is not engaged, the very community whose dignity, well-being, and health are being affected.

From the data gathered by the researcher through observations, the project was meant to address the issues of overflowing sewer systems, and wastewater that had adverse effects on the road. The road was effectively destroyed by the contractor, contracted to extend the pipes. When the researcher asked the councilor about the project that had such an effect, he stipulated that the project was a success and the contractor was working within the service-level agreement with the municipality.

5.2 *Objective 2 To identify strategies that can improve the planning and implementation of quality and sustainable sanitation infrastructure in Cosmo City Extension 6*

Nelson et al. (2021) argued that community engagement in issues of water and sanitation infrastructure is the backbone of sustainable development. The community embrace the planning, design, and maintenance of the sanitation infrastructure. The findings indicated that there is a need for engagement between the municipality and the community. This was further illustrated by the fact that the City of Johannesburg, first tried to destroy the back-room structures without community participation after they identified them as the chief causes of sanitation infrastructure depletion. Second, they contracted a private company to perform a rehabilitation project without discussing it with the community. This by and large failed. The failure of these initiatives meant that no proper assessment of the impact was done and the community that was affected was not engaged. The majority of the residents interviewed claimed they saw people digging pipes, but no information was provided.

6 CONCLUSION

Planning for sanitation infrastructure in post-apartheid South Africa, particularly within the context of Cosmo City Extension 6, stands as a testament to the multifaceted challenges and the strides made in pursuing quality and sustainable solutions. Cosmo City serves as a microcosm of the broader efforts aimed at redressing historical imbalances while addressing contemporary needs. The study shows that during the Apartheid era segregation and discrimination led to inadequate sanitation infrastructure in previously disadvantaged areas and the system persists post-apartheid. Planning for quality and sustainable sanitation infrastructure requires robust government policies, community engagement, and innovative approaches to sustainable sanitation infrastructure.

The findings indicated that post-apartheid South Africa has made significant efforts to redress the inequalities in sanitation infrastructure. The commitment has been reflected in a series of regulations and policies implemented to ensure quality and sustainable infrastructure. However, the implementation of these policies has been very limited or non-existent. The policies currently implemented do not encompass inclusive and participative planning. This means that the needs and concerns of the residents of Cosmo City are not taken into account, therefore the quest to provide an effective, sustainable, and resilient community is compromised. It is of paramount importance to state that planning for quality and sustainable infrastructure without applying a community-led total approach is devoid of the very principles of sustainable urban planning. Given such a background, it suffices to say the Cosmo City Extension 6 case exemplifies the complexities of planning for quality and sustainable sanitation infrastructure and perpetuated challenges in post-apartheid South Africa can be addressed through meaningful planning.

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Theme 10: Digital innovation in construction & digital transitioning

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Review of advances in computer-vision applications in construction industry

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ABSTRACT: Leveraging computer vision to automate construction progress monitoring and enhance construction safety has the potential to facilitate efficient infrastructure delivery. Despite the potentials of this area, awareness on advances remains low. Using a six-stage review method, this study examines the importance of computer vision in building infrastructure better, the challenges, current approaches and future directions necessary to deliver the technology effectively and efficiently. Findings were discussed based on 15 papers retrieved from Scopus and Web of Science database. The findings illustrate that significant research challenges encompass comprehensive scene comprehension, fluctuating tracking precision influenced by camera positioning, and the recognition of actions involving multiple equipment and workers. Challenges include absence of task-specific and measurable metrics for assessing extracted safety-related information, technical impediments stemming from the dynamic nature of construction sites, and privacy concerns. These challenges underscore the necessity for additional research in these domains.

Keywords: Computer Vision, Construction Industry, Artificial Intelligence, Machine Learning, Digital Technologies

1 INTRODUCTION

Construction is considered inherently a hazardous task that exposes construction workers to substantial risk of injuries and attrition levels (Musonda *et al.* 2024). Different solutions being proposed to keep workers out of danger in construction sites are employing manual approaches to identify developing hazards, which can make the process slower and prone to errors (Teizer 2015). However, to resolve the aforementioned challenges and to improve safety measures at construction sites, researchers have introduced various machine or Computer Vision (CV) technologies for automated fall hazard detection, construction site monitoring etc (Zhong *et al.* 2019).

Computer vision (CV) is one of the core techniques in the field of artificial intelligence (AI), aiming at developing a computer system that is capable of interpreting and understanding digital images (Reja *et al.* 2022). When a human sees an image, their brain can interpret the content based on previous experience, which has been enabled by the human visual system, As the human brain allows humans to process the images to learn and make decisions, computer vision aims to make a computer process and interpret visuals to enable a machine to make decisions based on the visual feedback (Duan *et al.* 2022). In recent years, applications of computer vision have exploded due to successes in deep learning and artificial intelligence (Seo *et al.* 2015). The growing rate of this technology is also observed in the construction industry to automate/assist tasks to make them more efficient and effective. Computer vision can be used in construction to support various tasks, which include but are not limited to safety monitoring, progress productivity analysis, and personnel management. The task of computer vision has multiple levels of complexity which starts with image reconstruction, object detection, tracking, and pattern recognition, and ends on image segmentation (Xu *et al.* 2019).

Studies indicate that the majority of construction accidents stem from human errors and interactions between humans and equipment. Consequently, an efficient vision-based safety monitoring system must be capable of identifying not just human activities but also equipment operations (Xu *et al.* 2021). A significant portion of safety risks persist undetected and unaddressed within intricate and ever-changing construction settings. For a vision-based hazard identification system to be practical and effective, it must exhibit a satisfactory degree of comprehensiveness and accuracy. Primarily, it is essential for the system to detect the majority, if not all, hazards present. Achieving this necessitates the development of a thorough hazard profile and knowledge base.

The adoption of computer vision is low, stemming from the need to advance research in the area and low awareness among professionals. Presently, there has been minimal critical examination of advancements in computer vision. Thus, to bridge this gap, the following objectives have been outlined, to investigate the advances in computer vision in the construction industry by examining importance, current approaches, applications, challenges and future directions. The paper began with an introduction that outlined the research background, followed by a description of the methodology employed. Subsequently, we discussed the findings derived from our review. The concluding section of our paper encapsulated our conclusions as well as the identified limitations.

2 RESEARCH METHOD

We employed a six-step review methodology to examine the advancements in computer vision applications within the construction industry as applied in studies such as (Jiang *et al.* 2021). The study aimed to investigate the significance, applications, current methodologies, challenges, and future trajectories in computer vision. The initial step involved defining the review's scope, setting the stage for an in-depth exploration of computer vision's role in construction. Our focus was to provide a comprehensive overview of the field's latest developments, barriers, applications, and prospective directions for future studies. This has been done in previous studies such as (Onososen and Musonda 2022); (Starzyńska-Grześ *et al.* 2023).

The second phase entailed identifying pertinent literature and documents through predefined search strategies encompassing data sources and keywords. We sourced academic articles from Google Scholar and Scopus Search Engine, comprising journal articles, conference papers, and book chapters. Specific keywords such as "Computer Vision, "AND "Challenges," AND "Applications," AND "Future Directions" guided our data retrieval process. Following data acquisition, the subsequent steps encompassed data collection and quality assessment, ensuring the inclusion of reliable and pertinent resources. Thorough text analysis aligned with the study's objectives facilitated the interpretation of results in the context of the broader research landscape (Tjebane *et al.* 2023). This is further outlined in Figure 1 below.

Figure 1. Research method.

3 FINDINGS AND DISCUSSION

3.1 *Importance, application and current approaches*

Computer vision is not just useful for identifying the elements of the ground. It is equally important to know where each one of these is placed, conclude whether these are correctly placed, observe what it is performing, and study or predict an event based on the detected mechanisms. Here, computerized positional detection using smart sensing cameras, deep learning (DL and CNN), and structured light scanning or time-of-flight imaging can do the job (Moragane *et al.* 2024). Moreover, as we gradually move ahead along the construction schedule, especially during the superstructure phase and the installation of mechanical, electrical, and other utility system, the task type and applications also drastically change (Gharib and Moselhi 2023). This involves a constant increase in the area through which the sensing camera has to survey or periodic inspection; therefore, the dataset will become colossal and real-time information is required automatically (Jeelani *et al.* 2018). In these cases, the authors have found that these cases can be automated based on the deep learning and computer vision concept. During the construction process, computer vision technologies are widely used, since direct contact with the object is not necessary and real-time results can be obtained (Zhong *et al.* 2019). Computer vision can measure the positions of an object or device using markers, thresholds, or other specific measures (Wang and Wong 2019).

The computer vision utilized in construction sites goes beyond merely taking photos. Through measuring, visual recognition, and analysis of image data in specific locations, the construction site is made a smart and automated construction site where positioning feedback and machine tracking can be provided to the computer with high precision (Starzyńska-Grześ *et al.* 2023). In industry settings, referring especially to manufacturing and construction sectors, computer vision technology automatically captures and computes the visual data and supports various types of decision processes by providing situational awareness and automated object reconnaissance. In the literature, CV-based applications in the construction industry can be seen based on two principal types (Jahangir *et al.* 2023). First, the literature presents usages of imaging, photogrammetry and computer vision applied to monitor defect detection, Evaluate Concrete's Finishing Using a Computer Vision-Based Approach and Computer Vision Analysis for Construction Health and Safety, monitoring, tracking and inspection of physical construction components (Liu *et al.* 2021). Photogrammetric techniques play a crucial role at the construction sites. Structure-from-Motion (SfM) is a photogrammetric technique for 3D point-cloud generation from connected 3D key points (Duan *et al.* 2022). Many research works have utilized this technique for safety monitoring, construction process monitoring, working condition monitoring etc (Deng *et al.* 2020). The second type applications focus on human and equipment tracking, mobility and positioning, gesture and language recognition, construction process sensing by using images and extracting data existent in the images. Among diverse computer vision-based construction applications, positioning and construction worker activity recognition and analysis have improved rapidly with advanced technologies such as information fusion, low complexity and learning (Xu *et al.* 2019).

Additional applications of visual feature detectors and descriptors in object detection within the construction industry encompass techniques such as the Scale-Invariant Feature Transform (SIFT), Histogram of Oriented Gradients, Haar-like features, and the Speeded Up Robust Features (SURF) (Lee *et al.* 2022). These methods extract a set of local visual characteristics to represent objects. Their notable advantage lies in their robustness against partial occlusion, as they capture features invariant to scale, illumination, and affine transformations.

Since 2017, deep learning methodologies have emerged as primary approaches for object detection and recognition. For instance, the region-based fully convolutional network (R-FCN) serves as a classifier for identifying heavy equipment on construction sites (Xu and

Wang 2023). Additionally, Faster R-CNN (region-based convolutional neural networks) has gained popularity. A significant advantage of Faster R-CNN over R-CNN is its enhanced speed, enabling real-time object detection (Guo *et al.* 2021). Object tracking stands as a significant focal point in computer vision research, particularly in the context of ensuring safety on construction sites by monitoring both workers and equipment. The primary objective of object tracking is to continuously locate a moving object of interest. This process typically involves detecting the object, assigning a unique identifier to it, and then tracking its movement across successive frames within a video stream. In the realm of tracking tasks, objects of interest can be delineated by their shapes, including skeletons, points, geometric figures, and contours, as well as by their appearances, encompassing colour, edges, and texture. Construction workers emerge as the primary focus of interest within this domain. Various tracking methodologies, such as Kernel tracking, Point tracking, and Silhouette tracking, have been employed to effectively monitor and track the movements of workers on construction sites (Wu *et al.* 2019)

The history of computer vision (CV) has undergone extensive advancements over the last several decades in the construction industry. Drones are widely used to automate the site survey for safety monitoring and to generate 3D models, and photogrammetry-based point clouds technologies gain substantial interest in architectural 3D modelling (survey) and internal space detection in existing buildings (Bonyani and Soleymani 2022). The computer vision techniques also has lead to significant advancements in calculating progress rates from the project images, and based on the analysis schedules are revised and optimized. With a specific objective of ensuring safety, musculoskeletal disorders, accidents, and falls are deadly risks in construction activities (Li *et al.* 2021).

To mitigate these risks, wearable devices as a real-time monitoring system have been widely applied recently. Recently, more role and time-specificity utilizing learned knowledge and real-time monitoring tasks have been proposed to address the aforementioned limitations. It is expected that we will see more cyber-physical system-enabled construction safety management platforms using these robotics and machine learning techniques in the future. Efficiently and effectively improving the safety management process will be the next research challenge for both the computer vision-based method as well as cyber-physical system paradigms. As an effort to realize such a challenge, we believe that future research will be well future the bridging of motion tracking, risk level calculations, and construction progress monitoring in a real-time manner on the construction site. Moreover, in the reflection of several types of construction safety risks, combining several sensors and other computer vision-based methods such as object detection and human identification on the construction site, incoherence in the reflection of the real-world information can be effectively handled together (Starzyńska-Grześ *et al.* 2023).

3.2 *Challenges*

The significant complexity in construction scenes-arising from the difficult and dirty environment of the construction sites-raised challenges such as occlusion, truncation, clutter, lighting variations, shadows, scale changes, and viewpoint variations (Wu *et al.* 2019). All of these factors impacts to the uncertainties of digitization results (e.g. multi-surface reconstruction). Moreover, robotics researchers indicate that difficulties of navigating in the construction scene (e.g. context changes and uneven terrain) have direct effects on the reliability and performance of knowledge on the performance and safety monitoring of construction sites and robotic systems. Additionally, labelling (e.g. locating, annotating, and describing) each construction element in the scenes in the static dataset and for the dynamic scene understanding, and monitoring learning models are required, which are very challenging and time-consuming (Yu *et al.* 2019).

On the other hand, the low structures of the crane cameras enforce the difficulty of featureless conditions. Another challenge is to classify a building element (either a brick, pipe, stone, stair, etc.) from the same category (e.g. brick-brick). Computer vision, or artificial intelligence in general, relies on accurate input data (Starzyńska-Grześ *et al.* 2023). These data include the scene kinematic and geometric construction, indoors or outdoors-known or unknown structures and mainly monitored by static, close-range vision sensors versus dynamic pieces of equipment on long ranges. Moreover, the processing of artificial and natural, bright and dark or thermal-light mixed datasets increases the complexities of the processing algorithms. Environmental issues, including chemical reactions occurring in the environment, material substance diffusion and external gas emission among others, seriously affect the visibility by refractive index mismatch and finally cause the fugitive smoke (Xu and Wang 2023). It may intensified by some condition, such as industrial activities, pour-push motion and mixing by human activities of local urban or rural systems in streets, roads, farms, field parks, port and pedestrian locations (Kumar *et al.* 2022). Typically, the most common and influential environmental factor affecting visibility is the weather in which rain, snow and fog are defined as poor weather conditions, In congested and highly-populated areas, smoke and exhaust dust can also be considered harmful and dense particles that degrade the visibility while wind influences the spray flow freely in the atmosphere (Seo *et al.* 2015). This spraying fog from canal freshwater or terrestrial freshwater can arrive largely to degraded visibility due to its smaller aerosol liquid such as high-speed winds in the coastal or urban areas.

All datasets intended for training computer vision models comes with a set of image-level annotations or object-level annotations. Weak annotators may not be able to express their thoughts clearly and, in such cases, the model might not learn anything from the training data (Kazemian *et al.* 2019). Often there are ambiguities while performing annotations as there are no strict rules for manual annotations. Annotating large-scale training data with greater accuracy seems to be difficult in a few particular cases. Thus avoiding the estimation error related to the subjective nature of manual annotation is not possible in such a case and has a compounding impact when annotating large-scale data sets drudgingly. Furthermore, to create a well-differentiated class, homogenous yet difficult datasets are recommended since trivial training data can bias any discriminate model. In order to address a complex annotation problem, it thus becomes beneficial to examine the estimation accuracy. Annotator positionality drives the training subset and testing subset - the pose of the construction-related items in images. The understanding of the site in the construction domain is difficult due to dynamic activities, occlusions, unpredictable variations, and complex environments.

DL-based methods are now popular in the construction domain due to superior features, end-to-end learning, self-learning, and high accuracy. A popular application is mask region-convolutional neural network (R-CNN) for worker safety distance elucidation, where R-CNN and its variants such as Region-based Fully Convolutional Networks, faster R-CNN, etc., which extend the R-CNN methods to improve the speed of detection (Xu and Wang 2023). Despite the progress made, several notable challenges persist in effectively tracking resources within construction sites. These challenges include variations in scale, occlusions, similarities in appearance, sudden movements, and background clutter. While 2D tracking outcomes are valuable, they may not always suffice for comprehensive assessments and analyses related to construction, such as evaluating productivity or ensuring safety. Therefore, endeavours to acquire the 3D position, direction, and velocity of construction objects are crucial (Guo *et al.* 2021). Although computer vision has facilitated progress in identifying individuals engaged in unsafe activities on construction sites through video surveillance, it may raise concerns regarding privacy infringement if individuals have not consented to be monitored.

Deployment of data acquisition equipment on a construction site is contingent upon obtaining consent from all parties involved. Surveillance devices have the potential to induce discomfort and evoke negative emotions among individuals being monitored. Moreover, awareness of surveillance may impede spontaneous or creative behaviors due to the realization that their actions are under scrutiny (Botao Zhong *et al.* 2019). While real-world application on intricate construction sites remains the most effective means of validating developed methods, there has been notably limited research conducted in ongoing construction sites. Emphasizing the significance of testing in genuine construction environments rather than controlled experimental setups in laboratories or testbeds has been advocated.

3.3 *Future directions*

Advances in computer vision, a subset of visual computing, have revolutionized quality management, progress monitoring, material management, defect detection, and safety management in the construction industry. Among visual computing techniques, machine learning and deep learning have provided exceptional results for various construction applications such as construction progress monitoring, safety management, defect detection, material management, and construction quality management (Manzoor *et al.* 2021). The performance of a deep learning model primarily depends on the quality of the data used to train and validate it. As the performance of a deep learning model primarily depends on data quality, efficient and effective management of data quality and annotation is paramount(Pour Rahimian *et al.* 2020). Quality, comprehensive annotation is essential for developing computer vision models; however, it is a time-consuming and costly process. Data quality and annotation are involved in almost all stages of developing a computer vision model, from creating a dataset to deploying a model in the real-world (Czerniawski and Leite 2020).

A poorly annotated, low-quality dataset limits the efficacy of a model. Data quality and annotation are critical and if not managed efficiently, they can have significant effects on the performance of final computer vision models. These challenges also provide ample opportunity for future studies and development in this area. For effective construction management, an automatic analysis of the site is a resourceful strategy, and it needs efficient computational methods and data. Besides, there are various sources for construction site images/footages such as robots, drones, and surveillance images. On-site workers can also capture the images of the installed structural element through smartphones. The ML algorithms are capable of finding hidden patterns, trends, and insights between different attributes in this dataset. An NN model, a subset of ML mimics the human brain function and learns with examples (Fang *et al.* 2018). The DL model is capable of learning and extracting features, and historically it was widely applied in image data as the dataset is highly suitable for DL (pictorial form and several channels for RGB). Therefore, DL applications in the construction site are escalating and illustrating the problems, key features, and future directions of the proposed deep learning models for construction site applications (Luo *et al.* 2020). Hazards such as restricted space to perform tasks, impeding objects, and trips and falls are significant factors to be addressed in spatially limited construction buildings. Identifying and correlating low-level visual features of pertinent behaviors, along with social and behavioural cues, with high-level safety climate factors such as management commitment to safety and safety attitudes is imperative. This endeavour entails recognizing group dynamics, such as interactions between supervisors and workers or among workers. Additional research is warranted to capture these group interactions through computer vision for enhancing health and safety in construction (Zhong *et al.* 2019)

The significance of associating behaviour cues with safety climate lies in its potential to offer an alternative for the long-term prediction of unsafe behaviours and accidents. Previous attempts at identifying unsafe behaviours through computer vision have been disjointed, lacking a holistic framework that addresses all conceivable unsafe behaviours. Furthermore, the absence of publicly available datasets dedicated to safety behaviour recognition in construction hampers progress (Wang *et al.* 2019).

A hierarchical framework for safety behaviour is essential, necessitating the development of various datasets at different levels to enable machine learning models to comprehend safety behaviours prevalent on construction sites. Progress in low-level recognition can facilitate high-level recognition, leading to more efficient and beneficial vision- and behaviour-based safety initiatives (Wang and Wong 2019). Future endeavours could focus on extracting semantic meaning from construction site scenes to enhance automatic hazard identification and health and safety monitoring. Additionally, integrating computer vision with workers' behaviour simulation models, such as agent-based safety behaviour models, holds promise for further advancing safety practices in construction.

4 CONCLUSION OF STUDY

Computer vision is an interdisciplinary field of study that enables computers to recognize and extract information from digital images and videos to make decisions and understand its subjects. This paper provides an overview of the latest advancements in computer vision technology and its applications within the construction sector, examining existing obstacles, recent progress, and prospects for future research. The findings suggest that the majority of prior endeavours have been concentrated on detection, recognition, and tracking within computer vision applications, leaving significant opportunities for advancement in assessment and prediction. Computer vision (CV) presents considerable potential for enhancing recognition and tracking performance. Moreover, attempts have been made to discern human and equipment behaviours across various levels of complexity, ranging from simple pose recognition to intricate interactions and events. Nonetheless, research focused on identifying unsafe behaviours has been somewhat limited. It is evident that computer vision technologies hold promise for augmenting existing safety management systems by streamlining hazard identification processes and enhancing workers' situational awareness. Future research endeavours could focus on identifying a broader range of safety behaviours, enabling the integration of computer vision techniques into behaviour-based safety programs to lessen the dependence on manual observation and analysis. Exploring the development of vision-based safety culture sensing systems presents an intriguing research avenue. Such initiatives would require interdisciplinary collaboration among social science, behavioural science, safety science, and computer vision disciplines to effectively measure and monitor safety culture using computer vision methodologies. Although this paper makes a valuable contribution, its findings are subject to certain limitations. Primarily, the criteria used for selecting databases represent a constraint. Future studies should encompass a broader range of metrics for a more comprehensive analysis. Additionally, the literature sample was restricted to English journal articles, potentially overlooking relevant studies published in other languages.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

The application of Industry 4.0 technologies in construction health and safety (H&S) management in Zimbabwe

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ABSTRACT: The construction industry faces H&S challenges because of a lack of functional occupational H&S management policies and technological advancement. The purpose of this study was to investigate the adoption of Industry 4.0 technologies to enhance H&S practices in the construction industry of Zimbabwe. Using a quantitative approach with an exploratory survey design, close-ended self-administered questionnaires were distributed in Harare and Bulawayo. The research results showed low adoption of the selected technologies with BIM being ranked first followed by drones and lastly wearable technologies. The benefits found include enhanced monitoring and supervision, improved safety training through virtual interactions, and enhanced hazard identification. The research made an important contribution to the body of knowledge and implementation of new H&S policies will cater to new technologies that aid safety. The study recommends that educational programs and government interventions be done to increase the awareness and adoption rate.

Keywords: Health and safety management, Industry 4.0, Adoption Rate, Developing Country

1 INTRODUCTION

Construction workplaces can have various undesirable impacts on the well-being of workers and it may result in numerous safety and health challenges (Chazireni and Chigonda 2018). This is a global problem where H&S challenges such as design process-related hazards, workers being unaware of hazards, risks related to the construction process and its activities, real-time monitoring of construction-related activities, workers handling heavy material and the experience of injuries continue to be experienced in the construction industry (Beale and Smallwood 2019). Construction sites are considered the most potentially risky, accident-prone parts of any environment, so there is a need for proper health, and safety practices (Opaleye and Talukhaba 2014). However, the deplorable safety management practices are damaging the reputation of the construction sector and its root cause is the lack of integration of core technology with the project activities (Akram *et al.* 2019). Additionally, it is unfortunate to note that the construction industry in Zimbabwe is still a very dangerous industry to work in because of accidents that emanate from fraudulent practices and the inability to adopt best practices (Nyoni and Bonga 2017).

On the other hand, Beale and Smallwood (2019) concluded that the intervention of the Fourth Industrial Revolution (Industry 4.0) technologies such as virtual reality (VR), drone technology, and VR-based health and safety training may help to address the above-mentioned problems. In support, Turner *et al.* (2020) mentioned that to improve the

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practices that the contractors conduct on-site, they have to utilize many opportunities that the Industry 4.0 revolution imposes on construction sites. Several definitions of Industry 4.0 have been put across. Nowotarski and Paslawski (2017) define Industry 4.0 as a concept relating to the idea of an industry revolution that integrates production processes with information technologies and techniques. The use of these techniques helps to automatically identify safety risk drivers and safety standards at all phases of the construction (Malekitabar *et al.* 2016). The essence of Industry 4.0 is to ascertain intelligent and smart operations and to revolutionize the management decision-making process when it comes to safety and health on construction sites as a way to reduce accidents (Turner *et al.* 2020). Despite this, Lau *et al.* (2019) assert that the construction industry has been reluctant to embrace the newly emerging technological practices. This study sought to identify the status of construction health and safety and opportunities presented by selected Industry 4.0 technologies to improve construction health and safety management.

2 LITERATURE REVIEW

Several procedures should be followed to reduce the number of accidents and move towards safe and zero-accident job sites (Irizarry *et al.* 2012). To achieve this goal, management should devise proper safety practices which both the workers and management should follow (Irizarry *et al.* 2012). Health and safety management practices are policies, strategies, procedures, and activities implemented or followed by the management of an organization targeting the safety of their employees (Razali *et al.* 2018). Practices of health and safety reduce risk, hazard, accident, and budget for a project although negligence has caused many human tragedies, loss of productivity, and delays in projects (Hashem *et al.* 2013). Ford and Tertrick (2011) found out that, involving workers in the safety management process is the key to an organization's safety performance as this is attributed to empowering the workers psychologically via their participation in safety committees. In another study, Teo *et al.* (2016) highlight that safety incentive programs should be adopted as a way to create a safety culture. More so, Wong & Soo (2019) added that regular inspection must be done on-site and it can improve safety performance by reducing the number of accidents on the construction site. This alone will be beneficial to the H&S practices and shows that there is a need for technological advancement in terms of this practice.

2.1 *Industry 4.0 and H&S management*

Although the logic of pursuing such a goal is obvious there are many non-believers in the sense that they do not believe it is achievable (Smallwood and Emuze 2016). To counteract this, Beale and Smallwood (2019); Demirkesen and Tezel (2021) point out that the intervention of Industry 4.0 technology in the construction industry comes as a solution to solve many problems faced including health and safety issues. According to Aslan (2019), accident rates could be decreased with the help of these technologies through increasing monitoring and measurement of the working environment. In support, Beale & Smallwood (2019) alluded that the construction industry heavily relies on manual observation to monitor and identify any potential hazards, and continuous monitoring for H&S becomes a challenge which then the introduction of the Industry 4.0 technology to solve. Management of site H&S represents a mitigating risk, allocating resources efficiently and making better decisions which can be made easily by the Industry 4.0 technologies (Aslan 2019). Wearable, drones, the internet of things, augmented reality, visual reality, and big data are key drivers of H&S management to reduce the risks (Aslan 2019). In support, Beale & Smallwood (2019) point out that the use of these technologies has a vast range of benefits and the potential to achieve better onsite H&S management, to promote healthier and safer working conditions. However, these technologies can be combined to produce a very effective product for managing health and safety issues on sites (Turner *et al.* 2020).

2.2 *Benefits employed by use of Industry 4.0 technologies on H&S management*

Despite the challenges faced with the use of Industry 4.0 technologies, several benefits can be gained from the adoption. Tepe (2021) highlighted the general benefits of adopting this technology as it lowers production costs, increases productivity, higher quality products and services, minimizes production time, and flexible production system. Similarly, Demirkesen and Tezel (2021) alluded that generally these technologies have an impact on workforce empowerment, and create efficient production processes in terms of construction and value chain. On the other hand, as far as H&S is concerned, Badri *et al.* (2018) point out that there is integrated OHS management, sophisticated tools, and standards for the management of occupational risks and equipment that is safer to operate and especially working environments and practices that are better supervised and controlled. Oesterreich and Teuteberg (2016) alluded to cost savings, time savings, on-time and budget delivery, improved quality, improved collaboration, and communication, enhanced safety, and improved sustainability as the benefits of using Industry 4.0 technologies. These benefits will emerge due to early detection and alerts that are given by these technologies (Aslan 2019).

2.3 *The H&S benefits of selected Industry 4.0 technologies building information modelling (BIM)*

BIM offers a wide range of benefits at various stages of the construction process and the use of BIM in the construction industry will bring about the issue of design for safety (Teo *et al.* 2016). Guo *et al.* (2017) point out that the integration of BIM can improve safety education and training, hazard identification, and design for safety. This is corroborated in a study conducted by Zhao and Lucas (2013), which highlights that simulation-based safety training programs can offer an engaging and interactive tool for training all construction workers on hazards and safe working procedures. BIM allows the designers to share, discuss, and explore the building project digitally before it is built virtually and come up with a design that considers all the safety aspects and builds better teamwork which reduces accidents onsite (Teo *et al.* 2016). This approach is consistent with the design of the safety program. More so, BIM can be used to raise safety awareness, identify hazards and risk assessments, enable the detection of possible problems during construction through visualization which considers safety at the earliest opportunity, track important H&S information relating to changes in design, equipment, materials and personnel (Teo *et al.* 2016). This will bring about enhanced safety planning during the design phase and also the construction phase which has the potential to ease the tension between production and safety Guo *et al.* (2017). The study by Azhar (2017) points out that BIM can be used to enhance the following practices, design for safety, safety planning, worker safety training, accident investigation, and facility and maintenance phase safety.

2.4 *Drone technology*

Drone technology is equipped with a video camera that provides images as well as real-time videos from a range of locations around the job site. This can be used by safety managers for safety inspections at any time in all different areas of the construction job site and provide feedback in real time (Beale and Smallwood 2019; Irizarry *et al.* 2012)). More so, unlike the traditional way of inspecting safety, this technology removes frequent walking and observation and is proven to increase the frequency of inspections and direct observation without interfering with any activity happening. Accident investigation will be made possible and simple by using pictures and videos captured to evaluate what would have transpired. They further highlighted that safety communication will be made easy by the use of drones because they may use voice transmitters on the drone and this will give direct communication or warning to the workers (Irizarry *et al.* 2012).

2.5 *Wearable technology benefits health and safety practices*

This technology brings about real-time hazard identification and management by tracking the location of workers, materials, and equipment providing warnings in real-time if workers are in dangerous zones, and making informative and safe decisions (Guo *et al.* 2017). Traditionally, workers are notified about potential hazards before they start to operate, and they depend solely on their experience and skills to manage both the identified and unidentified hazards. This gives a loop in safety monitoring and controlling which can be bridged so that hazards can be either eliminated or isolated. From the preceding discussion, it can be concluded that this technology can help to enhance human conditions and capabilities and thus reduce human error on construction sites. Wearable technologies improve accident investigations through the use of sensors or cameras attached to the wearables which record movements and quickly trace back the location of the incident. In addition, it enhances hazard identification, monitoring, and supervision of workers during work through the use of sensors that send an alarm to the workers notifying them of the hazard to be faced (Liu 2021). Table 1 presents a summary of the potential benefits of selected Industry 4.0 benefits for H&S management.

Table 1. Potential benefits of BIM, wearable devices, and drone technology on CH&S.

Item	Benefits	Source/Reference
Building Information Modelling		
BIM01	Safety education and training	Teo *et al.* 2016; Zhao and Lucas 2013;
BIM02	Hazard identification	Teo *et al.* 2016; Chan and Fung 2016;
BIM03	Design for safety/design hazard identification	Chan and Fung 2016;
BIM04	Risk assessments	Teo *et al.* 2016;
BIM05	Accident investigations	Teo *et al.* 2016;
BIM06	Safety Plan	Teo *et al.* 2016;
BIM07	Facility and maintenance phase safety	Azhar, 2017; Guo *et al.* 2016; Shukri *et al.* 2023 Azhar 2017;
Wearable devices		
WD01	Real-time hazard identification and management by tracking the location of workers, materials, and equipment	AL-Sahar *et al.* 2021; Guo *et al.* 2017
WD02	Enhanced communication (Issue danger warnings)	Changbum *et al.* 2019; Ibrahim *et al.* 2023; Liu 2021
WD03	Safety monitoring and controlling	Changbum *et al.* 2019; Liu 2021;
WD04	Accident investigations	Changbum *et al.* 2019; Ibrahim *et al.* 2023
WD05	Hazard identification and risk awareness	Changbum *et al.* 2019; Liu 2021
WD06	Strengthen Safety inspection and training	Chen *et al.* 2023; Liu 2021
Drone Technology		
DT01	Enhanced site monitoring	Beale and Smallwood 2019;
DT02	Real-time safety inspections and feedback	Beale and Smallwood 2019;
DT03	Enhanced accident investigation	Irizarry *et al.* 2012
DT04	Improves safety training	Sawant *et al.* 2021
DT05	Hazard identification (real-time)	Sawant *et al.* 2021;

The presentation in Table 1 shows that Industry 4.0 technologies offer several opportunities to improve health and safety management.

3 RESEARCH METHOD

The study adopted a positivist philosophy, wherein structured questionnaires were used to collect data from construction professionals in Zimbabwe relative to the implementation of Industry 4.0 technologies. The study adopted an exploratory research design because there is limited information about the use of Industry 4.0 technologies in the Zimbabwean construction industry. The data was collected from Bulawayo and Harare because the two cities house the largest concentrations of construction and consulting firms in Zimbabwe.

3.1 *Population and sample*

The study population comprised contractors registered in categories A to C by the Construction Industry Federation of Zimbabwe (CIFOZ), construction/project managers, and construction H&S officers. Contractors in categories A to C were chosen because they often execute big projects and are likely to adopt the technologies. According to Moyo *et al.* (2019) category A to C contractors reflect the most organizationally and technically competent, and financially stable companies in Zimbabwe. The study sought to include the entire population in this category.

3.2 *Questionnaire design and administration*

Close-ended questionnaires were used as the main data collection instrument because they are less expensive, quick, and convenient in terms of administration (Bryman 2004). The questionnaire also enabled researchers to collect standardized information in respect of the same variables for everyone in the sample selected and the researcher could contact many respondents quickly. The questionnaire was designed using an online platform, Survey Monkey, and administered via emails and WhatsApp platforms. The online survey was preferred because it is convenient and allows respondents to complete the survey in their own time and location (Neuman 2004). The questionnaire consisted of two sections. The first section of the questionnaire collected data regarding respondents' demographic profiles such as gender, education level, designation, and experience. The second section asked about the status of health and safety in the Zimbabwean construction industry and the potential benefits of selected Industry 4.0 technologies on construction health and safety. To improve the response rate, weekly reminders were sent to respondents. The study used literature to identify the benefits of selected Industry 4.0 technologies included in the questionnaire. Table 1 presents a summary of the benefits.

3.3 *Data analysis*

The collected was analyzed with the help of the Statistical Package of Social Sciences (SPSS) to compute descriptive statistics in the form of percentages, frequencies, and a measure of central tendency such as mean scores (MSs). The MSs were interpreted following the recommendations of Smallwood and Emuze (2014) as follows: 'MS $>$ 4.20 $\leq$ 5.00' = near major to a major/major extent, 'MS $>$ 3.40 $\leq$ 4.20' = moderate to near major/near major extent; 'MS $>$ 2.60 $\leq$ 3.40' = minor to a moderate/moderate extent'; 'MS $>$ 1.80 $\leq$ 2.60' = not at all to minor/minor extent'; MS $>$ 1.00 $\leq$ 1.80' = not at all. According to Ikediashi *et al.* (2012), a midpoint score of 3.00 was used as a benchmark where variables/benefits with MSs $\geq$ 3.00 are considered significant. A Cronbach's alpha coefficient was computed to assess the internal consistency reliability of the Likert scales used in the survey.

4 RESULTS AND DISCUSSION

4.1 *Status of health and safety*

Table 2 below shows how the respondents rated the construction health and safety status, indicating that it is not in a good state. This rating can be attributed to the fact that some companies still face injury incidents on-site due to the construction industry's lack of proactive health and safety practices. Adow (2013) highlighted that unpleasant health and safety status may be due to contractors' underpricing of their safety. More so, Chigara & Moyo (2021) revealed that the unfriendly state of affairs may be because the construction industry did not sufficiently adjust its approach to workers' H&S even in or before COVID COVID-19 era. Table 2 shows the Mean Score (MS) relative to the status of H&S in Zimbabwe. The Mean Score of 3.01 falls in the band "$>2.60 \leq 3.40$" which shows that respondents deemed the status to be in the range of poor and fair to fair. This may be ascribed to the lack of management's commitment to health and safety and poor worker's behavior in relation to H&S. As highlighted by Teo *et al*. (2008), the lack of an appropriate H&S culture in the construction industry of developing countries is the leading cause of poor H&S status causing workers to be less sensitive to safety issues.

Table 2. Health and safety status.

	Rating					
State of Health and Safety	1	2	3	4	5	Mean score (Ms)
State of Construction Health and Safety in Zimbabwe	1	12	34	9	3	3.01

4.2 *Adoption of the selected Industry 4.0 technologies in managing health and safety*

Respondents ranked the use of these selected Industry 4.0 technologies in managing H&S at their company from 1 (never) to 5 (always) and the results are shown in Table 3 below.

Table 3. Frequency of use of Industry 4.0 technologies to manage health and safety.

	Rating						
INDUSTRY 4.0 TECHNOLOGIES	1	2	3	4	5	Mean Score	Ranking
Building Information Management (BIM)	16	20	18	2	3	2.25	1
Wearable technology (smart hard hat, smart watch, smart vast, e.t.c)	24	14	9	7	4	2.15	2
Drone Technology	29	15	4	8	0	1.74	3

Given that the MSs for all the technologies, it suggests that respondents deem these technologies to be used to a minor as opposed to a major extent. The MSs for BIM and wearable technology are $>1.80 \leq 2.60$, which suggests that respondents deem the technologies to be adopted between a near minor and a minor/minor extent. The MS drone technology (MS = 1.74) suggests that the technology is used to a near minor extent. Overall, the results suggest that the technologies are inadequately utilized for H&S management in the construction industry. The results are corroborated by Nowotarski and Paslawski (2017) who identified the existence of a very large dose of skepticism to implement new technologies in their construction industry. During another study, Zhou *et al.* (2013) concluded that the construction industry is hesitant to adopt advanced technology in managing its H&S. Even in recent years' studies, Beale & Smallwood (2019) also found that respondents generally have limited exposure to these technologies.

4.3 *Benefits of the selected Industry 4.0 technologies on health and safety practices*

The respondents were asked to rate the potential benefits of selected technologies to health and safety practices based on a Likert-type scale from 1 (not significant) to 5 (v). The selected technologies are BIM, wearables, & drone technology. The results were interpreted with the following guidelines where $0.1 \geq \text{RII} \leq 0.28$ meaning not significant; $0.281 \geq \text{RII} \leq 0.46$ meaning of little significance; $0.461 \geq \text{RII} \leq 0.64$ meaning somewhat significant; $0.641 \geq \text{RII} \leq 0.82$ meaning significant and $0.821 \geq \text{RII} \leq 1.00$ meaning very significant.

4.4 *Benefits of BIM to H&S practices*

Table 4 below shows the potential benefits of using BIM on health and safety practices and how they were ranked using the Relative importance index (RII).

Table 4. Benefits of BIM on H&S practices.

Benefits to health and safety practices	RII	Rank	Overall Rank
Preconstruction Phase			
Enhances safety planning.	0.74	1	2
Enhance hazard Identification and risk assessments.	0.73	2	3
Enhances the integration of safety into the design (design for safety).	0.73	3	4
Improves hazard identification & elimination during design.	0.68	4	7
Improves site safety communication and collaboration between designers.	0.67	5	8
Construction Phase			
Enhances the monitoring and supervision of health and safety performance.	0.76	1	1
Improved Accident Investigation.	0.74	2	3
Improves worker safety training.	0.72	3	5
Enhances safety talks	0.70	4	6
Post Construction			
Enhance facility maintenance safety.	0.68	1	9

Table 4 above shows that respondents perceived that the use of BIM will mainly benefit more in the contraction phase as the highest-ranked was found there. Safety planning was ranked second, followed by hazard identification and risk assessment and integration of safety into the design (Design for safety). This trend can be attributed to the fact that if you do proper safety planning at the beginning of the project using this technology, it will be easy to monitor the plan and follow all the plans as this will result in reduced accidents. More so, the fact that BIM encompasses other components of other technologies makes it more effective in solving the challenges faced (Akinlolu and Haupt 2020). Pre-contract stage, enhanced hazard identification was ranked first with an RII of 0.73 followed by an increased design for safety with an RII of 0.73, and lastly improved safety communication with an RII of 0.66. This is attributed to the fact that the BIM has an element of safety in design that enhances those functions, and also modern architects are now more involved in the safety design issues to reduce accidents to happen and it will enable the contractors to price it nicely. In a related study, Azhar (2017) found that BIM improves safety through the ability to identify potential site hazards before construction and design out risks and hazards across all stages. BIM is an enabling technology with the potential to improve communication and the quality of information for decision-making (Ganah and John 2015).

During the construction phase, increased monitoring and supervision of works is ranked first with an RII of 0.76, followed by improved accident investigations. This is so because it makes use of visualization and simulations which can identify and minimize the discrepancy between work planned and work done and makes use of videos when it comes to accident investigation thereby simulating the whole construction process (Guo *et al*. 2017). The other benefits of BIM are enhanced safety talks with an RII of 0.70 followed by safety training with an RII of 0.62. This was opposed by Jones and Laquidara-Carr's (2017) study which found that the toolbox is important as the workers got more knowledge about the site visually without making them think a lot. Given that the respondents' rankings in terms of RII are greater than 0.50, it suggests that they perceive the benefits to be a major category of significance (0.641 to 0.821) meaning that BIM is considered to be more significant in helping to manage safety. This technology helps to have a safer working environment since all occupational risks would have been mitigated and this is in line with Zorzenon *et al.* (2022). According to Akinlolu and Haupt (2020), the management of accidents and injuries on sites can be easier when BIM technology is combined with visualization technologies and this alone will enhance many health and safety practices that are there.

4.5 *Benefits of wearable technology to H&S practices*

Table 5 shows the potential benefits of using wearable devices in health and safety practices and their ranking in terms of the Relative importance index (RII).

Table 5. Benefits of wearable technology on H&S practices.

Benefits to health and safety Practices	Rating					RII	Ranking
	1	2	3	4	5		
Improved health and safety planning.	2	3	13	22	19	0.78	1
Improves accident investigations.	1	2	16	24	16	0.78	2
Enhanced personal protective equipment (PPE).	1	5	15	24	14	0.75	3
Enhances Hazard identification during work.	1	5	16	23	14	0.75	4
Enhances monitoring and supervision of workers.	2	6	18	17	16	0.73	5
Improves safety training.	0	8	19	20	12	0.72	6

Improved H&S planning was ranked first with an RII of 0.78, followed by improved accident investigations with an RII of 0.78 and increased use of PPE with an RII of 0.75. The other benefits are enhanced monitoring and supervision of works with an RII of 0.73 and improved safety training with an RII of 0.72 were ranked 5th and 6th respectively with a higher RII for all the benefits, it can be inferred that respondents deem that the technology can contribute to the realization of these benefits to a greater extent. Previous studies show that wearable technologies have the benefit of tracking the location of the worker, and equipment and provide a proactive warning in real-time if the worker is in the dangerous zone thereby easing the process of monitoring (Guo *et al.* 2017).

4.6 *Benefits of drone technology to H&S practices*

Table 6 below shows the potential benefits of using drone technology on health and safety practices and their ranking in terms of the Relative importance index (RII).

Table 6. Benefits of drone technology on H&S practices.

Benefits to health and safety Practices	Rating					RII	Ranking
	1	2	3	4	5		
Increases the scope and frequency of monitoring and inspection.	2	3	16	22	16	0.76	1
Advanced accident investigation.	2	2	17	24	14	0.76	2
Enhances hazard identification and risk assessment.	2	3	13	26	15	0.76	3
Achieving real-time hazard management	1	4	21	17	16	0.75	4
Improves safety talks.	2	6	15	18	18	0.75	5
Improves safety training.	2	5	19	18	15	0.73	6

An increase in scope and frequency of monitoring and inspection with an RII of 0.76 was ranked first and this can be attributed to the fact that the drone moves in any direction without interrupting the work being done. This finding confirms the results of the study of Beale and Smallwood (2019) which found that drones provide real-time monitoring and information for inspections and hazard identification at different stages of the project. Improved accident investigations (RII = 0.76) and hazard identification and risk assessment (RII = 0.76) were ranked second and third respectively. Through the use of drone cameras and photos, the process will be made easy and safe (Jones and Laquidara-Carr. 2017), thereby contributing to improving H&S practices on site.

5 CONCLUSIONS AND RECOMMENDATIONS

The study sought to identify the potential benefits of BIM, wearable devices, and drone technology on construction health and safety in Zimbabwe. The results reveal that BIM, wearable devices, and drone technologies are not adequately used to enhance H&S. Nonetheless, respondents perceive that the technologies are beneficial to health and safety. Notably, the results perceive that BIM can enhance H&S performance through hazard identification and integrating safety measures during the design stage. During the construction phase, monitoring and supervision of health and safety can be enhanced which makes accident investigations to be easy. On the other hand, wearable technology is perceived to improve health and safety planning, accident investigations, and the use of personal protective equipment (PPE). The main benefits attributed to drone technology are increased scope and frequency of monitoring and inspection, advanced accident investigation, and improved hazard identification and risk assessment. Notably, the technologies help to address key contributor factors to accident causation on site. This calls for efforts to enhance to adoption of the technologies in H&S management. The results have several implications for policy and practice. The discrepancy between the adoption rate and potential benefits calls upon the government and construction stakeholders to promote the integration of such technologies in H&S management. Higher education institutions can facilitate such transitions through the integration of Industry 4.0 technologies into built environment curricula. In addition, the results highlight the need for the government to introduce policies that promote the importation of such technologies at optimum cost.

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Barriers to virtual reality implementation for health and safety training of construction workers in Zimbabwe

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ABSTRACT: Despite the enhancement of virtual reality (VR) in health and safety (H&S) training in the construction industry, Zimbabwe has had slow implementation due to contextual limitations. Determining existent barriers is fundamental to resolving this anomaly. Therefore, this study sought to identify barriers to VR implementation for H&S training of construction workers in Zimbabwe and examine their inter-relatedness. A questionnaire survey was conducted on construction professionals and H&S trainers in construction companies. The univariate mean score showed that high initial cost and technological unawareness were the highest barriers. Interrelated barriers comprised economic and technological constraints, business strategic limitations, VR utilisation inadequacy, stakeholder constraints and VR development challenges. The prominent role of the private sector is important in implementing VR in H&S training of construction workers by reducing implementation costs, especially in developing countries. The failure to withdraw in-depth qualitative data was a limitation of the study.

Keywords: Virtual reality, Health and Safety, Barriers, Construction workers, Training

1 INTRODUCTION

Due to the risks and dangers involved in H&S in the workplace, workers must be exposed to real-world situations in training through emerging technology like VR (Kim and Leem 2020). VR technology has been adopted and implemented in H&S training in various sectors and positive results yielded. The construction industry is considered one of the most unsafe industries so exposing workers to these situations through visualized assimilations enhances training and practical readiness. VR training entails coordinating and exposing the trainee to an imaginary accidental scene, conducting experiential training through visual assimilations, and commanding a corresponding positive practical response and readiness (Seo *et al.* 2021) and this propagates new training skills and methods in H&S training (Meyer *et al.* 2019). According to Gina *et al.* (2022), extensive opposition to implementing and uptake of modern technology like VR which brings simulation-based training that improves H&S has been noted, with construction firms preferring the traditional way of training particularly in developing countries like Zimbabwe. Although, studies on VR adoption in H&S training are common (Afolabi *et al.* 2022; Meyer *et al.* 2019; Seo *et al.* 2021) consideration of contextual differences in particular developing countries reveals relevant clusters of factors that need emphasis.

Therefore, this study sought to determine the barriers that hinder the implementation of VR in H&S training of construction workers in Zimbabwe. The concomitant objectives

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include identifying the individual barriers and determining the relationships among these barriers. Implementing VR in H&S enhances organizations' competence, increasing profitability, quality, and productivity (Afolabi *et al.* 2022). The following sections will consider the literature review of H&S training, the barriers to VR implementation of VR in H&S training, and the methodology used. The results will be presented and discussed. Finally, the conclusions and recommendations are outlined.

2 LITERATURE REVIEW

2.1 *Virtual reality in health and safety training*

The technology acceptance model underpinned this study. Zhang *et al* (2022) supported the use of the technology acceptance model in VR due to its ability to expose the barriers affecting its usage in the H&S training. Traditional training methods for H&S were theoretically conducted through lectures, audios and videos making construction workers fall short of the practicality of onsite H&S training (Yin *et al.* 2020). Dick (2021) and Miller (2022) ascertained that VR allows the simulation of H&S in real-world situations in which workers visually identify hazards, improve safety awareness, and become proactive workers. Through VR, workers develop ways of navigating risky situations that they may be exposed to and should make safety decisions that are also applicable to real-world situations (Cohen and McWilliams 2021). In health and safety virtual training, mistakes lead to virtual accidents that are not catastrophic but learning curves with no consequential outcomes. According to literature VR training can be adjusted to suit the perceived environment and type of skill to be developed during training (Ho *et al.* 2018; Kugler 2017; Wang *et al.* 2018). Kim (2019) noted that implementing experience-based safety education via VR technology is a motivator for H&S training. Furthermore, VR provides a homogenous, collaborative, and communicative environment for training, which is cost-effective. Despite virtual reality being a topical issue in developed countries, developing countries have taken a back stand on it, especially in construction.

2.2 *Barriers to VR adoption for H&S training*

Adopting VR into H&S training can improve how construction workers are trained, thus contributing positively to H&S training in the construction industry. However, most organisations, like the construction industry, face challenges when adopting technology. The barriers mined from previous studies are presented in Table 1.

Table 1. Barriers to VR implementation for H&S training.

Code	Barriers	Sources from previous authors
BRV1	High initial cost	Delgado *et al.* 2019; Evans 2018; Khudzaro *et al.* 2021.
BRV2	Technological unawareness	Cohen and McWilliams 2021; Gray 2016; Kayembe and Nel 2019; Maqsoom *et al.* 2023; United Nations 2019; United Nations 2022.
BRV3	Resistance to change	Delgado *et al.* 2020; Baniasadi *et al.* 2020
BRV4	Integration challenges	Sarkar *et al.* 2021: Saghafian *et al.* 2021.
BVR5	Technical limitation in the construction industry	Graeske and Sjöberg 2021; Peterson 2023; Tengere 2023.
BVR6	Health concerns to users	Afolabi 2023; Cunneen 2021; Delgado *et al.* 2020.
BVR7	Develop and disseminate quality educational and training activities and materials	Banerjee-Guénette *et al.* 2020; Malomane *et al.* 2021; Maqsoom *et al.* 2023;

(*continued*)

Table 1. Continued

Code	Barriers	Sources from previous authors
BVR8	Negative organisation culture towards innovation and new technology	Maqsoom *et al*. 2023; Saghafian *et al*. 2021.
BVR9	Lack of coordination within organisational departments	Baniasadi *et al*. 2020; Delgado *et al.* 2020; Dickinson *et al.* 2011; Miller 2022. Sarkar *et al.* 2021.
BVR10	Lack of client's interest towards VR adoption	Delgado *et al.* 2020; Maqsoom *et al*. 2023;
BVR11	Limited finance of the construction organisation	Delgado *et al.* 2020; Yin *et al.* 2020.
BVR12	Job insecurity to workers	Birkel *et al.* 2019; Malomane *et al.* 2021; Maqsoom *et al*. 2023.
BVR13	Lack of market knowledge about VR technology	Delgado *et al.* 2020; Wang *et al.* 2013; Yin *et al.* 2020.
BVR14	Time to explore immersive technologies	Delgado *et al.* 2020; Liagkou *et al*. 2020; Yin *et al.* 2020.
BVR15	Difficulty to assess and access experts' knowledge	Delgado *et al.* 2020; Liagkou *et al.* 2020; Saghafian *et al*. 2021; Yin *et al.* 2020.
BVR16	Insufficient demand for VR adoption	Baniasadi *et a*l. 2020; Delgado *et al.* 2019.
BVR17	Inter-phasing	Baniasadi *et al*. 2020; Cunneen 2021; Miller 2021.
BVR18	Understanding the VR language	Du *et al.* 2022; Evans 2018; Delgado *et al.* 2020; Lockwood and Erik 2020; Liagkou *et al*. 2020; Yin *et al.* 2020.

VR implementation requires high initial cost mainly due to investment in system modification, development processes, special skills, and technology necessary for supporting organizational objectives (Dalgado *et al.* 2019). These high costs become prohibitive for implementation by most construction organisations (Dalgado *et al*. 2019; Eric *et al*. 2015). In the construction industry cost is a major consideration for any probable investment to be undertaken (Khudzari *et al.* 2021) so the higher the cost the more the likelihood of VR implementation being abandoned. Despite the cost, the construction industry is not technologically acquainted with modern technology (Cohen and Williams 2021). According to Khahembe and Nel (2019), technological unawareness blinds away from the benefits of VR in H&S training from construction stakeholders. The United Nations (2019) ascertained that technology like VR, should be easy to use and adaptable to participants. The construction industry lacks the VR market knowledge (Wang *et al.* 2020; Yin *et al.* 2021) to enhance H&S training of construction workers.

Changing from the traditional H&S training systems to VR in the construction industry faces some worker resistance (Masqoom *et al*. 2020; Yin *et al*. 2021) and workers should be integrated into it amicably. Most construction organisations need to be aligned to dynamic thinking toward technological developments like VR since its implementation entails outright organisational support (Saghafian *et al*. 2021). Some construction organisations are technically incapacitated to afford the costs involved (Peterson 2023; Tengere 2023). Since VR is a new technology in Zimbabwe, few organisations provide technical services and support, thus making it expensive. According to Saghafian *et al*. (2021), VR requires experts to access and assess so that it complies with H&S training standards for construction workers. This pushes its implementation to be unfriendly to users and requires more time to explore its service (Liagkou *et al.* 2021). When more time is required, it becomes more costly for the organisation (Cunneen 2021). Another barrier noted after prolonged usage of VR is sickness like nausea, motion sickness, and headaches (Dalgado *et al*. 2019), so care must be taken when training workers.

3 METHODOLOGY

A positivist philosophy was instituted to interrogate quantitative data on the barriers to implementing VR for H&S training of construction workers, as supported by Delgado *et al.* (2020) and Masqoom *et al.* (2023). A total of 18 barriers were selected, as shown in Table 1. A questionnaire was distributed to all 152 construction companies in categories A to D, and project managers (PM) and H&S trainers (HST) formed the sampling frame. Construction companies registered with the Construction Industry Federation of Zimbabwe in categories A to D were considered because they have better material, human, and financial resources (Chigara *et al.* 2013). The questionnaires included two sections, with the first section focusing on respondents' demographics and the second section on their insights concerning the barriers to the implementation of H&S for construction workers where *1 – strongly disagree, 2 – disagree, 3 – neutral, 4 – agree, 5 – strongly agree.* An ethics clearance was sought and approved for this low-risk study. Ethical considerations included informed consent, voluntary participation, and confidentiality.

The Statistical Package for Social Sciences version 28 was used for data analysis. The reliability of the data collection instrument was confirmed through a Cronbach-alpha test. According to Taherdoost (2016), the Cronbach alpha test ascertains the degree to which the instrument provides constant, reliable, dependable results. This study obtained a value of 0.904, which shows that the data was reliable. The mean score for the results was construed in the following way: >4.20<5 (strongly agreeable), >3.40<4.20 (agreeable), >2.60<3.40 (somewhat agreeable), >1.80<2.60 (disagreeable) and >1.00<1.80 (strongly disagreeable), as adapted from Othan and Harinarain (2009). A statistical mean and standard deviation were calculated for each barrier, and the ranking of barriers was based on the mean. According to statisticians, a standard deviation between +/-2 is close to the actual value and can be accepted (Khudzari *et al.* 2019). Factor analysis was employed to expose sets of underlying factors that explain the relationships between the barriers (Field 2014). This is a data reduction technique used to compress data from many variables into a smaller number of variables (Kline 2008). It is also used to describe a cluster of detected variables with a comparable correlation. The KMO value of 0.811 was obtained, which is higher than the required of >0.50 and deemed excellent (Mao *et al.* 2015). Bartlett's test for sphericity, which tests the presence of a relationship between the barriers was used, and a significant value of 0.001 was noted, which was <0.05 (Chan *et al.* 2018). This shows a significant correlation between the data and its acceptance for factor analysis (Field 2014). On grouping the factors, exploratory factor analysis was executed using the principal axis factoring extraction method. Eigenvalue, which measures a variable's contribution to principal axis factoring, was used to determine a variable's relevance, and values of less than one, were kept (Adabre and Chan 2019). Factor loadings measure the correlation coefficient between an original variable and an extracted component, and factor loadings > 0.5 are considered essential and contribute to the component interpretation (Chan *et al.* 2018). The factors were named by analysing the common characteristics present in the barriers and everyday challenges brought by the barriers as well.

4 RESULTS AND DISCUSSION

4.1 *Profile of respondents*

The response rate was 41.45%, represented by 63 respondents from a population of 152 construction companies. The questionnaire asked respondents for voluntary participation and to maintain the confidentiality of results as an ethical consideration. This was adequate and supported by Baruch (1999), where a 60% +/- 20% response rate was reported to be sufficient.

Table 2. Profile of respondents.

Response Group	Construction industry category				Years of experience in the construction industry				Designation	
	A	B	C	D	1-2	3-5	6-10	>10	PM	HST
Population in category (136)	75	24	26	11						
Respondents (63)	46	5	7	5	10	29	14	10	45	18
Response rate (%)	61.33	20.83	26.92	45.45	5.87	46.03	22.22	5.87	71.42	28.58

Note- PM- project manager, HST- Health and Safety trainer.

Table 2 shows that category A companies were the most represented in the questionnaires distributed, with 61.33%. Most respondents had 3-5 years of experience in the construction industry. Although this shows a relatively inexperienced profile of respondents, it may reflect the existent experience levels in construction companies in Zimbabwe. Project managers were the most represented designation; however, health and safety trainers were also represented.

4.2 *Mean score ranking of barriers to implementing VR in H&S training of construction workers*

The mean score for the barriers spanned from 4.11 to 2.86. Twelve of the barriers have means between 4.11 and 3.40, which fall in the 'agreeable' range, with the rest falling in the 'somewhat agreeable' range. This shows that all the barriers significantly affect the implementation of VR in H.S. training of construction workers in the Zimbabwean construction industry. All barriers had standard deviation values between 0.988 and 1.311 indicating that the mean is close to the actual value (Khudzari *et al.* 2019). The high initial cost is the barrier with the highest ranked mean of 4.11. VR technology is expensive to purchase and install, and associated equipment and resources are required (Delgado *et al.* 2020). The least ranked is health concerns, as shown in Table 3.

Table 3. Mean score ranking of barriers to VR implementation for H&S training of construction workers.

Rank	Barrier	Mean Score	Standard Deviation	Interpretation
1	BVR1 - High Initial cost	4.11	1.161	Agreeable
2	BVR2 - Technological unawareness	3.97	1.145	Agreeable
3	BVR13 - Lack of market knowledge	3.83	1.153	Agreeable
4	BVR11 - Limited finance of the construction organisation	3.78	1.205	Agreeable
5	BVR8 – Negative organisational culture towards innovation and new technology	3.71	1.057	Agreeable
6	BVR3 - Resistance to change	3.71	1.221	Agreeable
7	BVR5 - Technical limitation in the construction industry	3.58	1.158	Agreeable
8	BVR10 – Lack of clients' interest towards VR adoption	3.54	1.147	Agreeable
9	BVR16 - Insufficient demand for VR adoption	3.54	1.200	Agreeable
10	BVR14 – Time to explore immersive technologies	3.45	1.118	Agreeable
11	BVR15 - Difficult to assess access experts' knowledge	3.45	1.212	Agreeable
12	BVR4 - Integration challenges	3.41	0.988	Agreeable

(*continued*)

Table 3. Continued

Rank	Barrier	Mean Score	Standard Deviation	Interpretation
13	BVR18 - Understanding the VR language	3.36	1.173	Somewhat agreeable
14	BVR9 - Lack of coordination within organisational departments	3.35	1.090	Somewhat agreeable
15	BVR17 - Inter-phasing	3.17	1.024	Somewhat agreeable
16	BVR7 - Develop and disseminate quality educational and training activities and material	3.11	1.210	Somewhat agreeable
17	BVR12 - Job insecurity to workers	3.03	1.311	Somewhat agreeable
18	BVR6 - Health concerns to users	2.86	1.248	Somewhat agreeable

4.3 *Relationships among the barriers to implementing VR in H&S training of construction workers*

From the factor analysis, five components were deduced as having eigenvalues of ≥ 1, which explained 70.782% of the total variance, with factor loadings extending between 0.508 and 0.848. The derived components, as shown in Table 4, are discussed hereafter.

Table 4. Relationship among the barriers to implementing VR in H&S training of construction workers.

Factor	Barrier to VR in H&S	Components				
		1	2	3	4	5
Economic and technological constraints	BVR1 – High initial cost	0.801				
	BVR2- Technological unawareness	0.738				
	BVR3 – Resistance to change	0.642				
	BVR4 – Integration challenges	0.763				
Business strategic limitation	BVR14 – Time to explore		0.741			
	BVR16 – Insufficient demand		0.674			
	BVR13 – Lack of market knowledge		0.664			
	BVR17 – Interphasing		0.574			
	BVR8 – Negative organisational culture towards innovation and new technology		0.570			
VR utilisation inadequacy	BVR5 – Technical limitation			0.564		
	BVR15 – Difficulty to assess			0.623		
	BVR18 – Understanding the VR language			0.775		
Stakeholder constraints	BVR9 - Lack of coordination				0.848	
	BVR10 - Lack of client interest				0.700	
	BVR11 – Limited finance				0.620	
VR development challenges	BVR6 – Health concerns					0.798
	BVR7 – Develop and disseminate quality education and training activities and material					0.651
	BVR12 – Job insecurity					0.508
Eigen value		7.170	1.911	1.566	1.085	1.009
Proportion of variance (%)		39.833	10.615	8.697	6.029	5.607
Cumulative variance (%)		39.833	50.449	59.146	65.175	70.782

4.3.1 *Component 1: Economic and technological constraints*

The first component is "economic and technological constraints", with a variance of 39.833 and 7.170 eigenvalues. It incorporates four barriers, namely high initial cost (BVR1), resistance to change (BVR3), technological unawareness (BVR2) and integration challenges (BVR4). Resolving economic and technological constraints is paramount for implementing VR in H&S training. Implementing digital infrastructure like VR requires a high initial capital outlay, training, and continuous skills development (Evans 2018; Khudzaro *et al*. 2021; Miller 2022). Adopting a new system requires human, infrastructure, technological, and capital resources to expedite cohesion in the organization's systems (Baniasadi *et al*. 2020; Delgado *et al.* 2020). Regulatory requirements like licensing should be met, and content development, data privacy, security, and legal issues to eliminate fear and despondency within the workers so that they do not resist the change coming with the introduction of technology (Cohen and McWilliams 2021; Maqsoom *et al*. 2023; United Nations 2019). The inception of VR requires compatible equipment and personnel to operate it. Adopting VR must be inclusive, harnessing careful planning and in-depth assessment and response to hindrances (Sarkar *et al.* 2021; Saghafian *et al*. 2021). The integration of challenges involves collaborating with other industry partners already engaged in VR usage.

4.3.2 *Component 2: Business strategic limitations*

The second component is called "business strategic limitations". The variance is 10.615 and the eigenvalue is 1.911. The BVR barriers regarded under business strategic limitations are time to explore the VR systems (BVR14), insufficient demand for VR (BVR16), lack of market knowledge (BVR13), interphasing (BVR17) and a negative organisational culture (BVR8). A new business venture requires time to strategise and plan for success. Including VR in existing business strategies is perceived to disrupt the current operational system and flow of the business because of VR's complexities (Maqsoom *et al.* 2023). The old and new systems have to interphase at some point, where both systems integrate into a hybrid, awaiting a complete transition. Much effort is required for successful transitioning. Highlighting strategies to be followed, engaging stakeholders, allocating resources, and identifying key performance indicators that VR must address in H&S training within the organisation is paramount. This may require time to explore and a positive attitude that clears a negative organisational culture so that all the possibilities available are looked at and when to invest in VR. A unified approach by different internal and external stakeholders can entail success. Some considerations like insufficient demand for VR in the construction industry and the time to explore may work against the business's plan to adopt VR. Business strategies are modeled to enhance organisational profitability, so strategies that require trial and error are mostly not welcome. However, stakeholders may gain appreciation through user participation and acquaintance with the product.

4.3.3 *Component 3: VR utilisation inadequacy*

The third component is "VR utilisation inadequacy", which has a variance of 8.697 and an eigenvalue of 1.566. Barriers that were considered for this component are technical limitation (BVR5), difficulty to assess (BVR15), and understanding the VR language (BVR18). VR equipment may not be compatible with all devices and operating systems (Cohen and McWilliams 2021). The aligned equipment, computer hardware, and software should be upgraded to the VR's technical specifications to counter latency, limited interactivity, and poor resolution (Peterson 2023). The information generated by VR is high-quality visuals and audio, which can be interfaced by special equipment requiring well-experienced and trained personnel to read and interpret (Liagkou *et al.* 2021; Yin *et al.* 2020). This improves VR's efficiency, compatibility, and usability in H&S training. The trainers and trainees should all be able to understand the language. The other shortfall in this regard is the inclusivity of VR in training people with disability and pregnant mothers with little to no effect. The utilisation of VR also extends to system maintenance, which is crucial to facilitate the smooth flow of the training process and even avoid trainees being stuck in the VR machine in case of breakdowns. This may require stand-by power supply sources and trainers who will quickly rescue trainees in case of developing faults, breakdowns, and conventional power cuts to allow safe evacuation.

4.3.4 *Component 4: Stakeholder constraints*

"Stakeholder constraints" is the fourth component and carries a variance of 6.029 and an eigenvalue of 1.085. The barriers are lack of coordination (BVR9), limited finance (BVR11) and lack of client's interest (BVR10). Stakeholder constraints emanate from the need for more information and knowledge about VR (Miller 2022) in H&S training. This may be due to a lack of coordination between VR suppliers and the construction industry stakeholders. Designing a VR specifically meant for H&S training is paramount since it provokes the client to invest in a product that outwardly performs the intended purpose. This boosts the implementation of VR in H&S training. Construction organisations mostly work on a limited budget, so they don't anticipate investing in technology they are not sure of. Continuous engagement from inception brings inclusivity, with contributions included in the development of a VR product that meets stakeholder's expectations. The heavy capital investment in construction projects limits technological investment. The internal and external stakeholders in the construction industry should work together and invest in VR for H&S training of construction workers (Delgado *et al.* 2020).

4.3.5 *Component 5: VR development challenges*

The fifth component was VR development challenges, which had a variance of 5.607 and an eigenvalue of 1.009. The barriers incorporated were health concerns (BVR6), developing and disseminating quality education and training activities and material (BVR7), and job insecurity (BVR12). VR development challenges impede implementation in H&S training through threats of job losses (Birkel *et al.* 2019), however, this is different in stable economies. The economic instability in most developing countries makes it challenging to keep pace with technological advancement as well. Also, some health effects like headaches, shoulder strain, blurred vision, and fatigue experienced by trainees pose a challenge (Cunneen 2023). For VR to be accepted as a training platform, continuous equipment improvement that eliminates these effects must be developed. Since VR is anticipated to enhance H&S training, quality education, material, and activities should be delivered during training (Riva and Mantovani 2019).

Implementing VR in H&S training of workers in the construction industry of Zimbabwe faces many barriers. Construction stakeholders must be acquainted with technological advances. VR must inform the business perspective of construction companies. There must be an enhanced focus on the effectiveness of VR in producing the intended results of H&S training. Stakeholders must view and perceive VR as a vehicle to meet the intended goals of H&S. Mitigating barriers may assist in developing VR that improves the training of workers in H&S in the construction industry.

5 CONCLUSION

Technological adoption like VR in H&S training is still in infancy in developing countries. VR brings the user into an interface with real and practical dimensions that make them see and experience real-life situations. The study sought to identify the barriers to VR implementation in H&S training of construction workers in Zimbabwe. High initial cost, technological unawareness, lack of market knowledge, and limited finance were the highest-ranked univariate barriers. Factor analysis revealed economic and technological constraints, business strategic limitations, VR utilisation inadequacy, stakeholder constraints, and VR development constraints as the major drawbacks to implementing VR in H&S training for construction workers. The construction industry must promote skills development by embracing modern technology. Implementing VR in H&S training of construction workers requires the private sector to significantly reduce implementation costs, especially in developing countries where resources are scarce. Professional bodies, training colleges, and universities should encourage participation through short courses and seminars on modern technology to bridge the knowledge gap since most stakeholders are not aligned with technological developments. The failure to withdraw in-depth qualitative data was a limitation of the study. Future studies can consider in-depth interviews and incorporate all stakeholders so that holistic interventions are uncovered and look at the intended benefits of VR in H&S training of construction workers in the construction industry.

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Potential of Internet of Things technologies in health and safety management in the Zimbabwean construction industry

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ABSTRACT: This study explores the potential of Internet of Things (IoT) technology to improve health and safety in Zimbabwe's construction industry, which has been plagued by high accident rates. Surveys were employed to collect data from 47 industry experts. Following inferential statistical analysis, the findings revealed that, while IoT is practical for incident monitoring, its adoption in Zimbabwe has been hindered by financial constraints, technological inaptitude, and infrastructural deficiencies. Therefore, the study concluded that, even though IoT is practical for incident monitoring, its adoption in managing health and Safety in Zimbabwe has been slow. Consequently, the study recommends the adoption of policy reforms, infrastructure investment and educational initiatives by key stakeholders to promote its usage. Despite limitations such as a small sample size and the everchanging IoT technological development, the study provides valuable insights for advancing construction health and safety management in Zimbabwe through IoT.

Keywords: Health and Safety management, IoT Technology, Incident monitoring, Construction industry, Zimbabwe

1 INTRODUCTION

Occupational health and safety issues are critical in enhancing the social well-being of the construction industry (Segbenya and Yeboah 2022). Construction industry is vital to any nation's economy (Yap *et al.* 2023). The industry contributes significantly to industrialised countries' GDP (Alaloul *et al.* 2021). Job-related accidents and non-ergonomic work settings make occupational safety and health difficult, especially in labor-intensive construction (Häikiö *et al.* 2020). These factors increase construction worker absenteeism and early retirement (Häikiö *et al.* 2020). Agriculture, forestry, mining, and construction have the greatest occupational death rates (Melchior and Zanini 2019). In 2020, OSHA reported 4,764 worker fatalities in the U.S., with a high number in construction and extraction. Construction has a higher occupational fatality rate than other industries, according to the ILO (2015). The Zimbabwean construction industry's safety and health performance is poor, with many accidents and deaths (Chipato *et al.* 2019). To overcome these safety issues, IoT (Internet of Things) and WSD (Wearable Sensing Device) technologies are being adopted (Alsharef *et al.* 2023; Sancheti and Sane 2022). These challenges can be addressed with real-time monitoring and improved worker safety through worldwide IoT adoption (Allam and Dhunny 2019). Labour dangers afflict Zimbabwe's building industry, despite its economic importance (Chigara and Smallwood 2016). Technology can improve safety management, but Zimbabwe is slow to implement it (Chigara and Moyo 2022). Significantly, limited

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research has been conducted to investigate the underlying factors contributing to these challenges within the construction industry. The study examined the level of usage and barriers to the adoption of IoT technologies in the Zimbabwean construction industry, in a bid to improve health and safety management on construction sites.

2 THE INTERNET OF THINGS

The Internet of Things (IoT), a term coined in 1999, signifies a network where physical objects are interconnected and communicate through the internet (Atzori *et al.* 2017). IoT has gained prominence with the advent of mobile devices, cloud computing, and data analytics, aiming to connect things at anytime, anywhere, and with anyone (Patel *et al.* 2016). The architecture of IoT includes a sensor layer for data collection, a network layer for data transmission, and a management service layer for data processing and analysis (Mrabet *et al.* 2020).

2.1 *Importance of IoT in HSM*

In the construction industry, integrating advanced technologies significantly enhances safety measures. Zhou *et al.* (2019) illustrated the value of sound alerts in providing timely hazard warnings to workers. Cho *et al.* (2018) explored how collision prevention technologies can identify unsafe site locations, reducing accident risks. Monitoring workers' postures is crucial for identifying ergonomic risks, a point emphasized by Antwi-Afari *et al.* (2018), while Zhou *et al.* (2019) advocated for an integrated approach to analyzing human-machine-environment risks for comprehensive safety management. Costin *et al.* (2019) discussed the importance of monitoring vital signs like heart rate and body temperature to detect health issues early. Technologies that enable access to hazardous environments are vital for worker safety (Thibaud *et al.* 2018). Sacks *et al.* (2013) highlight how technology facilitates risk and safety education in construction, improving safety awareness among workers. The role of IoT in ensuring the proper use of PPE is detailed by Häikiö *et al* (2020), enhancing compliance and reducing injuries. Martínez-Rojas *et al.* (2021) highlighted the need for addressing risks from falling objects, while Xu *et al.* (2022) emphasised the use of virtual fences to control site access and minimize OHS risks. Lastly, Costin *et al.* (2019) stressed the importance of enhanced communication and coordination for effective safety management in construction settings.

2.2 *Incorporation of IoT technologies in occupational safety and health management in construction*

The Safety and health incidents in construction adversely affect project outcomes and stakeholder well-being (Smallwood and Hingard 2013). The adoption of IoT technologies has emerged as a transformative approach to mitigate these challenges, enhancing the sector's safety and health management practices (Tender *et al.* 2022). Initial IoT applications in construction focused on basic monitoring for compliance with safety regulations using sensors to track environmental conditions and RFID technology to manage equipment and supplies, laying the groundwork for more advanced IoT applications (Ghosh *et al.* 2021; Turner *et al.* 2020).

The evolution of sensor technology and data processing capabilities has led to more integrated IoT solutions in construction HSM (Xu *et al.* 2022). Wearable devices monitor workers' health, and the integration of IoT with building information modeling (BIM) enhances safety management through real-time data and detailed digital representations (Tang *et al.* 2019). The latest phase in IoT's evolution in construction HSM is a shift towards predictive safety management and automation. Advanced analytics and machine learning enable the prediction of safety issues, while automation technologies like drones and robotics enhance monitoring and reduce human exposure to hazardous environments (Akinlolu *et al.* 2022). Research indicates a growing trend in utilising IoT sensor technologies for construction safety management. IoT applications in measurement, tracking, modeling, and forecasting offer significant potential to enhance safety and efficiency in the construction industry.

2.3 *Barriers in the adoption of IoT technologies in occupational safety and health management in the construction industry*

In the construction industry, several barriers impede the widespread adoption of IoT technologies. These barriers include the lack of integration between different technologies (Sigcha *et al.* 2018, Tabatabaee *et al.* 2022), limited scale of technology implementation (Zhou *et al.* 2017), scarcity of large and publicly accessible datasets for construction safety monitoring (Asadzadeh *et al.* 2020), deficiencies in onsite data recording (Zhou *et al.* 2017) and lack of technological proficiency among construction workers (Costin *et al.* 2019; Kumar *et al.* 2019; Okpala *et al.* 2020; Zhou *et al.* 2017). Other notable challenges include data privacy concerns (Häikiö *et al.* 2020), potential for reduced productivity due to the discomfort caused by wearable sensors (Antwi-Afari *et al.* 2018), lack of standardization in both hardware and software (Costin *et al.* 2019), inadequate governmental policies and incentives (Okpala *et al.* (2020) and unaffordable cost involved in the adoption of IoT in health and safety management in construction (Babalola *et al.* 2023).

3 RESEARCH METHODOLOGY

This study adopted a quantitative approach to explore IoT in HSM using a survey questionnaire tool. According to Gunter (2013), a quantitative approach enables the researcher to systematically investigate phenomena through observable and measurable data. Therefore, the quantitative approach was deemed appropriate for the study as it enabled the researcher to employ statistical analysis to validate assumptions, derive precise results, and predict outcomes, thereby enhancing the credibility and scientific rigor of the research findings. This approach combined paper-based and online methods to enhance data collection's scope and depth. The study focused on Zimbabwe's major cities, Harare and Bulawayo, where many construction companies operate. The study population comprised contractors registered with CIFOZ in categories A, B, and C. Stratified random sampling technique was employed to select different respondents who consisted of health and safety practitioners, quantity surveyors, engineers, project managers, and architects. Stratified sampling was used to divide the population into three groups (A, B, and C) and simple random sampling within each stratum. This technique accurately represented the industry's sectors and their IoT viewpoints in HSM. The study selected 103 individuals from 141 eligible Harare and Bulawayo respondents using Cochran's formula adjusted for finite populations. The survey questionnaire self-administered to the respondents using paper-based and web-based to acquire broad and inclusive data. The survey questionnaire had four sections: A-General Questions, B-Identifying IoT Technologies, C-Importance, and D-Barriers to Adoption. Section A covered gender, organisation, position, professional background, and highest academic degree. Section B highlighted IoT technologies from literature and invited responders to add more. In Section C, respondents ranked the relevance of IoT characteristics from the literature review on a likert scale, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, and 5=strongly agree. Section D listed 19 barriers to IoT adoption from the literature review and asked respondents to rank them on a likert scale (1=very little, 2=small, 3=neither small nor large, 4=large, and 5=very large). The quantitative data was analysed to determine IoT adoption, barriers, and the perceived importance of IoT technology in improving HSM in the construction sector. The study employed the Statistical Package for Social Science (SPSS) version 28, with a confidence level of 95%, to analyse demographic data and identify significant perception on the importance of IoT technologies in HSM. Inferential statistics were utilised for this purpose (Creswell and Creswell 2017). A Cronbach alpha reliability test was conducted to assess the stability and consistency of the questionnaire in measuring barriers to IoT adoption and the importance of IoT adoption, the test yielded an acceptance level of reliability which is very good with coefficients of.87 and 0.91 respectively (Ursachi *et al.* 2015). The analysis of variance (ANOVA) incorporated data regarding the gender, highest educational attainment, and years of experience in the construction sector of the participants. Additionally, it examined the interaction effects among these variables in relation to the perceived obstacles to the adoption of Internet of Things (IoT) technologies.

4 RESULTS AND DISCUSSION

4.1 *Response rate*

The response rate for participation was 46 %, represented by 47 respondents out of 103 construction companies, 21 out of 40 building contractors, 20 out of 43 civil contractors, 2 electrical contractors out of 13 contractors and 3 out of 7 mechanical contractors from a population size of 141. This is an acceptable response rate, according to Sanders *et al.* (2016), 30 respondents are acceptable for a survey.

4.3 *Demographic information of respondents*

Table 1 presents the respondents' demographic information regarding gender, designation, educational qualifications, profession, contractor's background and tenure within the company.

Table 1. Demographic information of participants.

Category		Frequency	Percentage
Gender	Male	37	79
	Female	10	21
	Total	47	100
Designation			
	Site Manager	10	21.3
	Quantity Surveyors	15	31.9
	Senior QS	4	8.5
	Architect	1	2.1
	Junior QS/Engineer	1	2.1
	Engineer	11	23.4
	Senior Engineer	3	6.4
	Health & Safety Officer	2	4.3
	Total	47	100
Work experience			
	1-5 years	10	21.3
	6-10 years	15	31.9
	11-15 years	12	25.5
	16-20 years	7	14.9
	25 + years	3	6.4
	Total	47	100

(*continued*)

Table 1. Continued

Category		Frequency	Percentage
Education qualification			
	National certificate	1	2.1
	Diploma	12	25.5
	Bachelor's degree	22	46.8
	Master's degree	12	25.5
	Total	47	100
Background of contractor			
	Building	21	44.7
	Civil	20	42.6
	Civil & Building	1	2.1
	Mechanical	3	6.4
	Electrical	2	4.3
	Total	47	

As shown on Table 1, the male-dominated sample (78.7%) aligns with the industry's typical gender demographics (Suresh *et al.* 2023). The majority of respondents were Quantity Surveyor (15 respondents, 31.9%), followed by Engineer (11 respondents, 23.4%) and Site Manager (10 respondents, 21.3%). Also, the results indicate that most of the respondents were educated, with most of them being holders of bachelor's degree (22 respondents, 46.8%), followed by diploma holders (12 respondents, 25.5%) and master's degree (12 respondents, 25.5%). The respondents were predominantly engaged in building works (21 respondents, 44.7%) and Civil (20 respondents, 42.6%). Additionally, most respondents' work experience ranged between 6-10 years (15 respondents, 31.9%) and 11-15 years (12 respondents, 25.5%), which those with below 5 years (10 respondents, 21.3%) were distant third. The varied experience levels among respondents offered a broad perspective on IoT adoption, reflecting different levels of openness to technological innovation.

4.3 *IoT technologies in use in the Zimbabwean construction industry*

Magnetometers and Sensors low adoption rate (31.9%) either suggests a lack of awareness or perceived relevance, or possibly cost barriers to wider implementation (Yap *et al.* 2022). Electrocardiograms (ECGs) minimal use (10.6%) could indicate perceived irrelevance, high costs, or a lack of necessary expertise within the industry (Gandhi *et al.* 2023; Xu *et al.* 2022). Infrared Sensors moderate adoption (38.3%) signifies recognition of their utility, yet also points to potential barriers like cost or technical complexity (Yap *et al.* 2023). Noise Sensors relatively low usage (36.2%) could reflect alternative noise monitoring methods or a prioritisation of other safety measures (Newman *et al.* 2021). RFID (Radio-Frequency Identification) higher adoption rate (59.6%) highlights the perceived utility of RFID in asset tracking and safety management (Xu *et al.* 2022). Bluetooth widespread use (85.1%) underscores Bluetooth's accessibility, cost-effectiveness, and versatility in supporting IoT applications (Patel *et al.* 2022; Tabatabaee *et al.* 2022). GPS (Global Positioning System) high usage (93.6%) reflects GPS's critical role in enhancing safety and operational efficiency through precise tracking (Xu *et al.* 2022).

Thermistors and Sensors limited use (17.0%) suggests a lack of perceived necessity or potential barriers like cost and technical integration challenges (Yap at al. 2023). UWB (Ultrawideband) even split in adoption (46.8%) points to emerging interest, with room for growth as its benefits become more recognised. Gyroscope and Sensors lower adoption (27.7%) might indicate niche applications or potential unawareness of their benefits in safety management. BIM (Building Information Modelling) and Data Analytics substantial use

(68.1%) indicates recognition of BIM's value in project planning and risk management, aligning with digital transformation trends.

Surveillance Cameras high adoption (89.4%) underscores their importance in monitoring safety practices and enhancing site security (Zhang *et al.* 2020). Drone Technology significant use (76.6%) highlights drones' role in safely accessing hazardous areas, showcasing an innovative approach to risk management (Yap *et al.* 2023). Virtual Reality (VR) Tools moderate adoption (44.7%) for safety education suggests an emerging interest in immersive training solutions (Babalola *et al.* 2023). Smartphones universal usage (100%) reflects the integral role of smartphones in facilitating communication and accessing IoT applications (Thibaud *et al.* 2018).

Other IoT Technologies mentioned by respondents include gas detectors (4.3%) which are used in detecting hazardous environments., Although The inclusion of gas detectors is mentioned by a small fraction of respondents, it underscores the industry's recognition of specific safety risks and the adoption of targeted IoT solutions to mitigate them.

In a summary, the data reveals the level of IoT adoption in Zimbabwe's construction industry, highlighting areas of significant integration, such as GPS and smartphones, alongside technologies with room for increased utilisation, like VR tools and gyroscopes.

4.4 *Barriers to the adoption of IoT technologies in the Zimbabwean construction*

The analysis of perceived barriers to the adoption of IoT technologies in the Zimbabwean construction industry reveals a spectrum of challenges that stakeholders must address to foster broader acceptance and integration of these technologies. The individual perceived barriers are depicted in Table 2 and are explored further. The identification of cost as the primary barrier echoes a common theme in technology adoption across various sectors, emphasizing the need for cost-effective solutions and clear demonstrations of return on investment to convince stakeholders of the value of IoT implementations, Babalola *et al.* (2023).The emphasis on the need for improved governmental policies and incentives, as well as enhanced technical training, highlights a crucial area where public-private partnerships could play a transformative role Okpala *et al.* (2020). By aligning policy initiatives with industry needs and investing in workforce development, stakeholders can create a more conducive environment for IoT adoption Okpala *et al.* (2020). Concerns about data privacy and the technical challenges associated with IoT technologies, such as the need for offline sensor networks and high computational efficiency, underscore the necessity for ongoing research and development, Zhou *et al.* (2017); Häikiö *et al.* (2020). Addressing these issues requires a collaborative approach involving technology providers, industry practitioners, and regulatory bodies to develop standards and best practices that ensure the effective and secure use of IoT. To overcome these barriers, the respondents' suggestions for increased training, stakeholder engagement, senior management commitment, educational programs, and national fundraising initiatives provide a roadmap for action. These recommendations highlight the importance of a multi-faceted strategy that addresses financial, educational, and policy-related challenges to unlock the full potential of IoT technologies in enhancing health and safety management in construction.

Table 2. Barriers to the adoption of IoT technologies.

Barrier	N	Mean	Std. Deviation	Rank
Cost of implementing IoT technologies	47	4.06	1.092	1
Poor governmental policies and incentives	47	4	0.978	2

(*continued*)

Table 2. Continued

Barrier	N	Mean	Std. Deviation	Rank
Lack of technical training	47	4	1.142	3
Lack of off-line sensor network	47	3.89	1.108	4
Challenges of data privacy issues	47	3.85	0.978	5
Low reliance on the technology	47	3.72	1.015	6
The lack of proper lighting for smooth functionality	47	3.62	1.134	7
Challenges arising from physical interactions	47	3.6	1.014	8
Lack of high computational efficiency	47	3.6	1.035	9
Limited scale of technology implementation	47	3.57	1.137	10
Safety hazards-workers ignoring prompts from IoT devices	47	3.55	1.08	11
The need for continuous monitoring	47	3.51	1.3	12
Lack of integration between technologies	47	3.45	1.017	13
Productivity reduction due to wearable sensors	47	3.45	1.017	14
Lack of publicly available large datasets	47	3.4	1.136	15
Limitations on hardware and software and lack of standardization in efforts	47	3.32	1.024	16
Lack of heavy batteries	47	3.32	1.086	17
Deficiencies in onsite data recording	47	3.3	1.102	18
Challenges of false alarms	47	3.3	1.102	19
Valid N (listwise)	47			

4.5 *Importance of IoT in HSM*

The respondents' responses regarding the perceived importance of IoT technologies in enhancing health and safety management are shown in Table 3. The survey assessed the perceived importance of IoT technologies in enhancing health and safety management, with mean scores ranging from 3.55 to 4.49 on a 5-point Likert scale, where 1 indicates "Strongly Disagree" and 5 indicates "Strongly Agree". The responses suggest a generally strongly agree that IoT technologies are important for various aspects of health and safety management. The highest mean score of 4.49, indicates to a very large extent that IoT technologies significantly enhance communication and coordination in health and safety management (Costin *et al.*2019). The second-highest score of 4.43 suggests respondents also to a very large extent agree that IoT technologies are important for providing sound alerts for timely hazard warnings (Zhou *et al.* 2019). With a mean score of 4.32, respondents agree that IoT technologies play a key role in accessing and assessing complex and hazardous environments (Thibaud *et al.* 2018). The technology's role in preventing collisions by detecting unsafe site locations is also highly valued, scoring a mean of 4.19. Both monitoring vital signs and personal protective equipment (PPE) usage aspects received a mean score of 4.09, indicating agreement that monitoring workers' health and ensuring proper usage of personal protective equipment are important functions of IoT technologies, (Häikiö *et al.* 2020). Creating a virtual fence received the lowest mean score of 3.55, which still shows agreement but indicates it is seen as less important compared to other IoT functionalities (Xu *et al* 2022). The study's findings demonstrate a clear recognition among construction industry professionals of the significant role IoT technologies can play in enhancing health and safety management. The highest-ranked aspects—communication and coordination, and timely hazard warnings—suggest that technologies which offer immediate and clear benefits in preventing accidents and facilitating efficient safety management are most valued.

Table 3. Perceived importance of IoT technologies in enhancing HSM.

Importance	N	Mean	Std. Deviation	Rank
Enhance communication and coordination	47	4.49	0.748	1
Hazard indication with sound alerts for timely warning	47	4.43	0.853	2
Accessing and assessing complex and hazardous environments	47	4.32	0.887	3
Collision prevention by detecting unsafe site locations	47	4.19	0.851	4
Monitoring vital signs for workers' health management	47	4.09	0.88	5
Ensuring proper usage of personal protective equipment	47	4.09	1.018	6
Integrated analysis of human-machine-environment risks	47	4.02	1.011	7
Challenges arising from physical interactions	47	3.6	1.014	8
Lack of high computational efficiency	47	3.6	1.035	9
Limited scale of technology implementation	47	3.57	1.137	10
Safety hazards-workers ignoring prompts from IoT devices	47	3.55	1.08	11
Monitoring workers' postures to identify ergonomic risks	47	3.98	0.967	12
Providing risk and safety education in virtual environments	47	3.96	1.083	13
Regulating risks related to falling objects	47	3.96	1.021	14
Creating a virtual fence to control site access	47	3.55	1.138	15
Valid N (listwise)	47			

5 CONCLUSION

The exploration of IoT technology adoption in Zimbabwe's construction sector highlights both the industry's readiness and the challenges it faces in enhancing health and safety management (HSM). The study found that, while industry professionals recognize IoT's potential to improve communication, hazard detection, and site safety, significant barriers like high costs, inadequate government policies, and a lack of technical training hinder its widespread adoption. To surmount these challenges and fully leverage the potential of IoT, this study advocates for several strategic measures: introducing government incentives and establishing clear standards, investing in specialised training programs, promoting Public-Private Partnerships (PPPs), implementing comprehensive data protection protocols, integrating IoT with widely used devices to lower expenses, encouraging an innovative workplace culture, launching pilot projects to demonstrate the benefits of IoT, engaging stakeholders actively, continuously evaluating IoT's influence on HSM, and formulating gender-inclusive approaches. Therefore, the findings could aid policymakers and relevant stakeholders in facilitating IoT integration, promoting a safer and more technologically advanced construction industry in Zimbabwe. However, the sample size used and the everchanging IoT technological development might pose limitations in generalising the results, although the findings offer valuable theoretical and practical contributions. Hence, future studies could employ a larger sample size to validate the current findings, as well as exploring the financing strategies to enhance the adoption of IoT technology in managing Health and Safety issues in the Zimbabwean construction industry and the Global South.

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Competencies required to manage risks in Industry 4.0 era: Perspectives of Zimbabwean construction project managers

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ABSTRACT: The advent of Industry 4.0 has brought new risks that construction project managers should manage in the construction industry. This study sought to investigate the required construction project managers' competencies in Zimbabwe to manage risks in the I4.0 era. Utilising a quantitative approach, 55 questionnaires were administered to gather insights from construction project managers in Zimbabwe. Through statistical analysis, the findings highlight the importance of both hard and soft skills particularly technological literacy, data analysis, strategic thinking, communication, and adaptability in managing risks associated with I4.0 technologies. The study concludes that while hard skills are fundamental in addressing risks in the I4.0 era, soft skills are more critical. Consequently, it is recommended that construction project managers be trained in soft skills. However, the results of the study cannot be generalised to all contexts, though the findings could be useful in informing policy, curriculum, and strategic decisions in the construction industry.

Keywords: Competencies, Construction project managers, Risks, Industry 4.0, Zimbabwe

1 INTRODUCTION

The construction industry is undergoing a significant transformation with the advent of Industry 4.0 (I4.0), characterised by the integration of cutting-edge technologies such as artificial intelligence, big data, and the Internet of Things (IoT) (Kagermann *et al.* 2013; Lasi *et al.* 2014). This digital revolution has brought about unprecedented opportunities for improvement in productivity, efficiency, and innovation, but also introduces new risks and challenges (Chui *et al.* 2016; World Economic Forum 2018). Effective risk management is crucial to project success, and construction project managers must possess specific competencies to navigate this complex landscape (Hillson 2002; PMI 2017). Industry 4.0 termed Construction 4.0 in the construction industry is seen as an enabling force that will usher in an evolution of the construction sector and revolutionize its practices and techniques. In a study by De Pace, Manuri and Sanna (2018), it was discovered that Industry 4.0 has potential to deliver extraordinary levels of growth and productivity over the coming decades.

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In developed countries like the UK, Construction 4.0 strategy aims to reduce construction period by 50% through applied research in digital design, cutting-edge materials, and innovation in new technologies resulting in a reduction in carbon emissions by 50% and overall and life-cycle costs by 33% (HM Government 2013). Macdougall (2014) noted that the German government announced its "Industry 4.0" strategy and selected nine key technologies, such as big data, self-aware robots, and simulations, as future drivers for its construction industry. The Japanese government is also supporting "Construction 4.0" strategy and is pushing for "I-Construction" to cope with the productivity degradation caused by the expected manpower shortage of the construction industry in the future (Lee and Park 2022). The Chinese government announced its "China Manufacturing 2025" strategy, which focuses on ten key areas such as Information Technology, digital control, robots through innovation, quality, and green development (Li 2018). Baul and Park (2022) note that these policy trends are considered as a center of the key strategy for the development of the construction industry in the future. Adoption of I4.0 in construction is aimed at enforcing a complete electronic form of the construction process—from project preparation, budgeting, building approvals, construction management, and building management (Maskuriy *et al.* 2019).

Governments in most developing countries including developed nations have taken strides toward the adoption of I4.0 in the construction industry (Chigara and Smallwood 2021; Maskuriy *et al.* 2019; Mpofu and Nemashakwe 2023), though little has been done to ensure the competencies of construction project managers are updated to enable effective management of risks within the technology era in Zimbabwe. Studies undertaken in Zimbabwe have focused on I4.0 challenges and opportunities for construction project health and safety management in Zimbabwe (Chigara and Smallwood 2021). Others reviewed the state of preparedness of Zimbabwe to adopt I4.0 technologies and others studied the adequacy of human capital for the I4.0 revolution era in the mining industry (Mhlanga *et al.* 2023; Mpofu and Nemashakwe 2023). Studies indicated that Zimbabwe lacks institutional, infrastructural, and human capital needs for I4.0 effective integration of all sectors. Few studies have been undertaken studies on competencies required by construction project managers but these were general and lacked alignment to risks in the I4.0 era (Moyo and Chigara 2023). Thus, there seems to be a dearth of research on the competencies required by construction project managers especially in Zimbabwe to manage risks in this new era (Muzenda 2017). The construction industry in Zimbabwean faces unique challenges, including infrastructure gaps, skills shortages, and economic uncertainty, which are exacerbated by the I4.0 era dynamics (Mutenheri and Chigwende 2017; Ncube and Phiri 2019).

This study aims to address this knowledge gap by exploring the perspectives of Zimbabwean construction project managers on the competencies required to manage risks in the I4.0 era, providing valuable insights for industry stakeholders, policymakers, and educators seeking critical competencies.

2 COMPETENCIES REQUIRED BY CONSTRUCTION PROJECT MANAGERS TO MANAGE RISKS ASSOCIATED WITH INDUSTRY 4.0 ERA

I4.0 dominates how businesses in the construction industry are conducted consequently impacting construction project managers' roles and responsibilities (Al-Mughairy and Shrivastava 2022). As skills and competencies are changing in direct proportion to technological changes associated with Industry 4.0, job upskilling will be required (Simion *et al.* 2018). Consequently, construction project managers' skills in risk management need to be upgraded to align with the emergence and dominance of Industry 4.0 technologies. Various authors (Aljneibi 2020; Al-Hammadi 2021; Al-Mughairy and Shrivastava 2022; do Vale, Nunes and de Carvalho 2018; Vazirani 2010; Win *et al.* 2018) have pointed out key construction project manager competencies that can assist in effective risk management in the Industry 4.0 era.

Al-Hammadi (2021) and (Romero Gázquez *et al.* (2021) highlight the skewing of construction project managers' competencies towards strategic thinking skills, advanced communication skills, and skills to use ICT tools to manage teams' and stakeholders' expectations. On the other hand, PMI (2018) identifies six digital age skills critical for construction project managers: data science, security and privacy knowledge, innovative mindset, data-driven decisions, legal and regulatory compliance knowledge, and collaborative leadership skills. Additionally, Varizani (2010) categorises construction project managers' competencies in I4.0 as social intelligence, emotional intelligence, and cognitive competencies. As presented by Varziani, social intelligence competencies include relationship management and social awareness, while emotional intelligence competencies refer to self-awareness and empathy. Furthermore, the same author described cognitive competencies as enshrining systematic and analytical thinking skills.

do Vale, Nunes, and de Carvalho, (2018) established four categories of construction project managers' competencies in I4.0: behavioural, technical, managerial, and contextual. Al-Mughairy and Shrivastava, (2022) argue human related management competencies can be substituted by more efficient digital management skills in some project stages. This means that human-related management competencies will have more importance in the initiation and planning stages, due to the high project team interaction associated with this stage. In contradiction, Win, Thee, Kham, and Saing (2018) claim that construction project managers' competencies are skewed toward interactive skills with stakeholders. Construction project managers will be more relevant in undertaking those responsibilities that technology cannot undertake such as creating project agreements and project resource management.

Al-Hammadi (2021) recognises that speed will be of utmost importance in the I4.0 era, and therefore, problem-solving, decision-making, negotiation, and exceptional communication skills will be highly valued. Aljneibi (2020), however, believes that construction project managers must be equipped with skills that allow them to possess comprehensive knowledge of cyber-physical systems such as experience with technology, predictive algorithms, and extensive data analysis to aid in managing risks in the I4.0 era.

Project management operations are almost static however, technology has changed how project interactions occur. Literature has shown the influence of technology in project monitoring, communication, information dissemination, and construction activities. This entails the increased use of technology for operations that traditionally require manual effort. In the context of risk management, technology has come to automate manual operations implying the reliance of the project manager on data capability skills. Digital capability skills include automation and mechanisation, cloud computing, 3D printing, simulation, robotics, system integration, and competitive intelligence (Romero Gázquez *et al.* 2021).

However, studies on the construction project manager's competencies in I4.0 have not been undertaken in Zimbabwe. (Moyo and Chigara 2023) researched on expected competencies of project managers in Zimbabwe, however, their study was not conclusive in the sense that it did not cater to the changes that have been brought to the construction project manager's skills base by IR4.0. The adoption of Industry 4.0 in construction operations is still in its infancy (Chigara and Smallwood 2021), attributable to a lack of digital capability skills which are pivotal to enhancing its uptake. Digital capability skills identified by (Al Amri *et al.* 2021; Fitsilis *et al.* 2018; Liu *et al.* 2022; Ribeiro *et al.* 2021; Romero Gázquez *et al.* 2021) are thus crucial for effective construction project risk management in IR4.0. Studies show that the construction industry experiences skills shortages, infrastructural deficiencies, and economic uncertainty (Muzenda 2017; Ncube and Phiri 2019).

Therefore, it is essential to investigate the competencies required by Zimbabwean construction project managers to manage risks in the I4.0 era. Considering the different competencies proposed by various scholars, there is unanimity among scholars that the competencies to be possessed by construction project managers should be transformed to be commensurate with the expectations of I4.0. However, the nuances associated with the competencies deemed most critical, show that the actual competencies required by construction project managers in each context remain debatable. Therefore, the study has compiled a list of competencies from the literature that the construction project manager should possess for effective risk management in the I4.0 era as shown in Table 1.

Table 1. Key construction project manager competencies necessary for risk management in the context of Industry 4.0 era.

Flexibility/adaptability
Lean and agile project management
Analytical and logical thinking
Problem-solving skills
Technical skills*
Effective language/communication skills
Ability to transfer knowledge
Speed in management of unforeseen events
Ensuring that there is accuracy in capturing information and ensuring that the information is acted upon*
Familiarization with modern methods of construction
Digital technologies leadership skills*
Ability to follow the latest trends in a landscape of continuous change
BIM skills as an enabler of data*
Experience with innovative technologies*
Intercultural skills
Comprehension of cyber-physical systems*
Ability to be compromising and cooperative
Influencing/persuasion skills
Deep domain knowledge*
Ambiguity tolerance

Source: Adapted from Vazirani (2010); do Vale, Nunes and de Carvalho (2018); Win, Thee, Kham and Saing (2018); Aljneibi (2020); Al-Hammadi (2021); Al-Mughairy and Shrivastava, (2022); PMI (2018; 2017).

3 RESEARCH METHODOLOGY

This study adopted a quantitative approach. According to Bryman (2016), quantitative methods allow the systematic collection and analysis of numerical data. A self-administered survey questionnaire tool was employed to collect data on the key competencies required by construction project managers in the I4.0 era. The list of competencies shown in Table 1 was given to the respondents to rank on a Likert Scale of 1 to 5 where 1 showed less importance and 5 most importance. The questionnaires were distributed to the respondents via an online survey, where respondents were allowed to answer the questions at their convenient locations and time. Questionnaires were favored in the current study since they are a relatively cheap and fast way of collecting quantitative data while ensuring respondents with anonymity (Creswell 2013). As argued b), well-designed questionnaires have the advantage of easing the data analysis since the responses will be easy to aggregate. Hence, the study benefitted from the said advantages. The study used stratified random sampling to select 55 respondents who comprised architects, engineers, quantity surveyors and contractors, registered with the Institute of Architects Zimbabwe (IAZ), Zimbabwe Institute of Quantity Surveyors (ZIQS), Zimbabwe Association of Consulting Engineers (ZACE)/Construction Industry Federation of Zimbabwe (CIFOZ) respectively. The selected respondents were suitable for the study because of their experiences and (or) expertise in executing construction project management roles on most construction projects. The study was delimited to Harare and Bulawayo since 90% of the major construction companies that contribute to 95% of the major construction activities in Zimbabwe are situated in these two cities (CIFOZ 2024). Thus, data obtained from these two cities fairly represents the entire population within the Zimbabwean context. Before collecting data, (Cronbach 1951) alpha test of reliability was used to estimate the internal consistency of the research instrument. Field (2013) posits that the coefficient varies from zero (0) to one (1); and a range of 0.7 to 1 is generally acceptable for Cronbach alpha while values of 0.6 and lower are considered unsatisfactory. For this research study, the internal reliability was tested on scale questions using Cronbach's coefficient alpha and the cut-off point of 0.6 was unreliable. Table 2 shows the study's sample profile. The collected data were tabulated and analysed using Relative Importance Index (RII) and mean scores to assess the most important competencies to effectively manage risks in the I4.0 era to construction project managers in Zimbabwe.

Table 2. The sample size computation.

Population Category	Population Size	Sample Size
Quantity Surveyors	22	3
Engineers	38	4
Architects	46	5
Contractors	433	43
TOTAL	539	55

According to Creswell (2014), the minimum requirement for a credible sample is 10% of the population for a population above 300 subjects. Since the population was heterogeneous, the study adopted proportionate stratified random sampling to ensure fair representation of the different population categories in the study's sample size. The quantitative approach was adopted in the study to gain a wider perspective on the views of respondents since much of the research undertaken in the area has mainly utilized literature (Al Amri *et al.* 2021; Grzybowska and Łupicka 2017; Mpofu and Nemashakwe 2023; Ribeiro *et al.* 2021) creating problems of generalization of the findings to other contexts.

4 RESULTS

4.1 *Response rate*

Of the 55 questionnaires that were distributed to the selected respondents, 53 were successfully returned by the respondents, constituting 96% response rate. This response rate is acceptable since it aligns with Grimmer and Bialocerkowski (2015). Furthermore, Creswell (2014) argues that the response rate for online surveys generally ranges from 20% to 30%.

4.2 *Demographic information of respondents*

Table 3 presents the respondents' demographic information regarding work experience.

Table 3. Demographic information of respondents.

Category		Frequency	Percentage
Work Experience			
	Less than 6 years	16	30
	6 to 10 years	19	36
	11 to 15 years	18	34
	Above 15 years	0	0
	TOTAL	53	100

As shown in Table 3, the results indicate that 19 respondents, representing 36% had 6 to 10 years of experience, followed by 18 (34%) respondents with 11 to 15 years of experience, while 16 (30%) of the respondents had less than 6 years of experience. Considering that most respondents, 37 (70%) had over 6 years of experience, this guaranteed the depth of respondents' knowledge and experience required to contribute by construction project manager's competencies in risk management, within the industry 4.0 technologies, thereby improving the validity of the gathered data.

4.3 *Competencies required by construction project managers in managing risks associated with the I4.0 era*

The respondents were asked to rank the competencies required by construction project managers in managing risks associated with the I4.0 era based on their usefulness and relevance. Table 4 shows the results obtained from the study. The results show that the 13 competencies listed in the table have mean scores ranging from 4.0 to 4.43. Based on the means scores and RII, the respondents viewed the identified competencies as most important to construction project managers in managing risks during the I4.0 era. The top-ranked competencies include flexibility/adaptability with a mean score of 4.43, lean and agile project management with a mean score of 4.40, analytical and logical thinking with a mean score of 4.36, problem-solving skills with a mean score of 4.36 and technical skills with a mean score of 4.36. However, 7 competencies were ranked lowly as indicated by the mean score of below 4.0. These include ambiguity tolerance with a mean score of 3.32, deep domain knowledge with a mean score of 3.32, influencing/persuasion skills with a mean score of 3.75, ability to be compromising and cooperative with a mean score of 3.85, comprehension of cyber-physical systems with a mean score of 3.87, intercultural skills with a mean score of 4.89 and experience with innovative technologies with a mean score of 3.94. Although the stated factors are useful to construction project managers, the study found that they were not the most critical compared to others who scored 4.0 and above.

Table 4. Competencies required by construction project managers in managing risks associated with the Industry 4.0 era.

Competency	Mean	RII	Rank
Flexibility/adaptability	4.43	0.89	1
Lean and agile project management	4.40	0.88	2
Analytical and logical thinking	4.36	0.87	3
Problem-solving skills	4.36	0.87	3
Technical skills*	4.36	0.87	3
Effective language/communication skills	4.32	0.86	6
Ability to transfer knowledge	4.32	0.86	6
Speed in management of unforeseen events	4.21	0.84	8
Ensuring that there is accuracy in capturing information and ensuring that the information is acted upon*	4.21	0.84	8
Familiarization with modern methods of construction	4.09	0.82	10
Digital technologies leadership skills*	4.04	0.81	11
Ability to follow the latest trends in a landscape of continuous change	4.04	0.81	11
BIM skills as an enabler of data*	4.0	0.80	13
Experience with innovative technologies*	3.94	0.79	14
Intercultural skills	3.89	0.78	15
Comprehension of cyber-physical systems*	3.87	0.77	16
Ability to be compromising and cooperative	3.85	0.77	16
Influencing/persuasion skills	3.75	0.75	18
Deep domain knowledge*	3.42	0.68	19
Ambiguity tolerance	3.42	0.68	19

*Construction Project Manager's Competencies more aligned to I4.0

5 DISCUSSION OF RESULTS

The study results show that the competencies that were being ranked had mean score ratings that were above 3. Although all the competencies reviewed in the study are important for risk management, technical skills, accuracy information capturing, digital technologies skills, Bim skills, experience with innovative technologies, deep domain knowledge, and cyber-physical systems were found to be more critical in I4.0-related risks in Zimbabwe. Flexibility/adaptability was ranked highly with a mean of 4.43. It means that project managers are expected to be flexible in the I4.0 era where project complexity is a major driver of changes in the discharge of responsibilities. This corroborates the view of Rezende and Blackwell (2019), that construction project managers are expected to be flexible and rapidly adapt to new conditions. Al-Hammadi (2021) also supports the importance of flexibility competence in the industry 4.0 era's use of technologies, expectations, and situations. This would offer a smart approach to problem-solving by emphasising learning through interaction, responsiveness, adjustments, feedback, and recognition of complexity and ambiguity inherent in situations (Dalcher 2020). Al-Hammadi also recognises that "adaptability" supports construction project risk management by enforcing more collaboration and team communication necessary for handling and coping with industry 4.0 changes. "Flexibility" is therefore an enabler for construction project risk managers to cope with rapid changes aligned with technological advancements.

Furthermore, the respondents also highly rated the importance of "the ability to apply lean and agile project management techniques" in risk management. These findings corroborate with Aljneibi (2020) arguments for including lean construction and agile project management techniques in construction operations. Construction risk management in the IR4.0 era requires swift decision-making processes geared to make the most of opportunities that are presented by technology while reducing the resultant threats from its use. Also, construction project managers "should be competent with the new technical and soft skills requirements associated with industry 4.0 technologies as shown in Table 4. These skills include technical, accuracy in information capturing, digital technologies leadership, Bim, experience with innovative technologies, comprehension of cyber-physical systems, and deep domain knowledge. These results align with several scholars (Al Amri *et al.* 2021; Liu *et al.* 2022; Ribeiro *et al.* 2021; Romero Gázquez *et al.* 2021) who emphasise the importance of the construction project manager's awareness and ability to utilise specialized technology and computer skills in the IR4.0 era. Essentially, the more expertise and technical knowledge the construction project manager has, the greater their effectiveness in managing risks and effectively delivering construction projects in the I4.0 era.

The study also identified traditional competencies such as analytical and logical thinking, problem-solving, communication skills, transference of knowledge, intercultural skills, and persuasive skills as relevant in I4.0, thus aligns with extant literature (Grzybowska and Łupicka 2017; Liu *et al.* 2022; Ribeiro *et al.* 2021). Al Amri, Khetani and Marey-Perez (2021) also points that the construction project manager needs to be competent at disseminating the knowledge that cannot be copied or learnt by machines.

6 CONCLUSION

The study aimed to investigate the required construction project managers' competencies to manage risks in the I4.0 era in Zimbabwe. This study has identified key competencies, including technological literacy, data analysis, strategic thinking, communication, and adaptability, as essential for navigating the complexities of Industry 4.0. Considering the array of skills observed as critical, the study concludes that both soft and hard skills are required in varying degrees by construction project managers to commensurate with the demands of the I4.0 era. The findings highlight the need for construction project managers to develop a proactive and adaptive approach to risk management, leveraging I4.0 technologies such as artificial intelligence, big data, and the Internet of Things (IoT). By cultivating these competencies, construction project managers in Zimbabwe can mitigate risks, optimize project outcomes, and contribute to the growth and development of the construction industry in the country. In conclusion, the I4.0 era has brought about unprecedented changes in the construction industry, necessitating Zimbabwean construction project managers to acquire specific competencies to manage risks effectively. Therefore, the study recommends that construction project managers adopt the identified critical competencies to manage risks effectively associated with the I4.0 era. The study's recommendations provide a foundation for industry stakeholders, policymakers, and educators to develop targeted training programs, frameworks, and policies that support the development of these critical competencies, ultimately enhancing the resilience and competitiveness of Zimbabwe's construction industry in the I4.0 era. Although the results are insightful, they cannot be generalised without caution due to the limited sample size and geographical delimitation. Therefore, future studies could broaden the study by considering all the towns in Zimbabwe or conducting comparative studies in other countries.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Student information system efficacy for BIM readiness in higher education institutions

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ABSTRACT: The aim of the study was to establish the Student Information System (SIS) efficacy in readiness for BIM adoption in a selected public university in a developing country (Zambia).with focus on students ‘and staff perspectives. The study used mixed methods to collect and analyze data for this research. Online structured questionnaires were received from students and staff members in eight schools on the main campus. The total number of student participant questionnaires retained was 322 while those for staff members were 79 inclusive of staff members and school administrators staff members. The results from the study indicate that the SIS was evaluated as good because it met the primary student and staff requirements at school and department levels. Despite the SIS meeting the primary requirements, challenges associated with the SIS were established as: traffic congestion, inconsistent internet connectivity and outdated SIS infrastructure rendering it not ready for BIM adoption.

Keywords: SIS, efficacy, effectiveness, higher education, BIM readiness

1 INTRODUCTION

Student Information System (SIS) also known as the “Portal” is a self-service environment or platform for students, prospective students and employees. SIS is an administrative environment for university staff to conduct their daily operations such as student management, library and staff services. It is an information environment for all levels of faculty and staff to carry out their reporting, extractions of data and also for information analysis. Over the past few decades, universities world over has been experiencing new paradigms in the way they manage and run students’ information due to the proliferation of ICTs and its applications such as web-based SIS (Lubanga *et al*. 2018). Web-based student information platforms are information systems that use internet web technologies to deliver information and services to organization (Lubanga *et al*. 2018). Bhatnagar *et al*. (2016) have revealed that Information Systems (IS) have become the backbone of most organisations. Seneler and Demirkol (2018) observed that effective SIS meet staff and students’ requirements but also increase sustainability of academic workflow. In order to prevent user errors, maintain users’ tasks and increase users’ satisfaction towards the system, usability study is essential for SIS.

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A local public university that is utilising SIS was identified in Zambia for research on how its SIS was performing with respect to students and staff members requirements and expectations.. According to Georgiadou (2019), Reliability and performance of the technology are frequently reported disadvantages of the adoption of BIM software. While many studies have focuses on SIS alone, this study links SIS and BIM training in higher education institutions. Further the study cited openness and availability of data as a perquisite to adoption of BIM. By evaluating the efficacy of the SIS at the institution, the readiness to adopt BIM in the teaching curriculum was established. There was no known report on the performance of the SISs triggering the study whose main aim was to evaluate the efficacy of the SIS at a public university in meeting students' and staff needs in readiness for BIM adoption through a survey done using semi structured questionnaires.

2 LITERATURE REVIEW

2.1 *Definition of SIS*

The concept of Information Systems (IS) emerged in the early 1960s (Marrero 2007). Another study by Obasi et al (2013) defined a SIS as a software application that is used in an education establishment to manage student data. Well-designed student information management systems support many functionalities and serves as the gateway to the university's academic operations through the Online Student Portals (OSP) as the component of the system for the students (Secreto 2015). The main objective of the Student Management System is to track all the details of students from the first day students enroll in their courses until they complete their course, this information can be used for all reporting purposes, tracking of attendance, progress in the course, completed semester years, exam details, assignment detail, final exam results and post-graduation management.

2.2 *Types of SISs*

SISs exist in many forms and names such as Student Management Systems, School Administration Software and Student Administration Systems (Seneler and Demirkol 2018). Campus Information System (CIS), University Classroom Management Information System, Education Management Information System (EMIS), and Student Information Management System (SIMS) (Kunda and Chama 2016). SIS houses many functions which include: providing record management of past, present and future students covering aspects of enquiry, application, enrolment, academic performance and history, allowing for billing and fees management, processing important events such as graduations and examinations, programming classes, reporting operational, assessment monitoring, storing examination results and management issues and feeding data into numerous other specialist systems (Seneler and Demirkol 2018). SISs are known to have a common goal which is to improve the efficiency and effectiveness of services which university students received (Kunda and Chama 2016). Despite SIS being referred by different names their main purpose is to manage students' and related institutional data.

2.3 *Functions and benefits of SISs*

SISs have lots of functions such as providing record management of past, present and future students covering aspects of enquiry, application, enrolment, academic performance and history, allowing for billing and fees management, processing important events such as graduations and examinations, programming classes, reporting operational and management issues and feeding data into numerous other specialist systems (Mukerjee 2012). It helps in managing even the minutest details of the student in a highly organized way. From enrollment to handling inquiries, tracking students' progress, sending reminders and notifications, the students' system does it all (Xiaoming and Fengjiao 2012). They are also used for managing procedures such as application, registration and tracking Student's records. A Student Management System (SMS) handles the administration part of students that includes; admission, examination records, assessment process, finance, room allocation, general communication e.g., notices, transcripts, students' union electronic voting, mobile text messaging, examination results feedback (Maere 2011).

Student Management Systems benefits both the administration and students in almost all Higher Education Institutions. SIS has many documented benefits which include among other online interface embedded in the college's website and maintenance of student information (Bharamagoudar *et al.* 2013), efficient and consistent running of institutional affairs, quick and accessible flow of information, automation of daily routine tasks, promotion of decision-making process of the institution (Goldstein and Katz 2015) management of portals to track schedules, attendance, courses, invoices /payment dues (Chikanta 2022). Despite the benefits, the SIS is not without hindrances and challenges.

2.4 *Factors that reduce the efficacy of SIS*

Literature presents many factors that prevent SISs from being effective in institutions of learning. Some of these include poor quality of the information system, poor information presentation, lack of adequate strategies or knowledge when adopting such systems (Barret 1999) overwhelmed installed capacity resulting in a slowed down system, lack basic computer literacy skills to effectively use the system, lack of senior management support, and lack of technical support (Shah 2014), lack of user-friendly software for analysing test results at the school level and lack of end-users' training (Carnoy 2004).

2.5 *Effectiveness of an information system*

Effectiveness provides for how users can achieve their goals with accuracy and completeness in a specified context of use (Borbely 2011). Huber (1990) indicated that effective systems should provide information that would speed up decision making processes. Those that design and implement information systems in education system should consider the needs of the users who are students in this case (Datmow and Park 2009). For instance, an effective Student Management System provides a simple interface for maintenance of student information Bharamagoudar *et al.* (2013). Additionally, SIS should be error free enabling users who are students to receive expected desired results at all times (Wayman et al. 2004).

3 RESEARCH METHODOLOGY

3.1 *Research design*

The study set out to establish the efficacy of the SIS in the university by categorizing staff members, students and support staff in different groups in order to compare the responses. Only results for students and staff members are reported in this paper. All the eight (8) schools on the main campus were targeted with a population of 8056 for the students at the time of collecting data. This study took a quantitative method approach in collecting data and analyzing data due to the many factors that required quantitative analysis. Targeting all the schools provided more credible and accurate results on the efficacy of the SIS.

3.2 *Respondents and sampling*

Semi-structured questionnaires were collected from 366 students. A sample of 169 for population of 300 and 370 for a population of 10, 000 Krejcie and Morgan (1970). Given the aforementioned a sample of 366 is adequate given that its population is 8056. Stratified random sampling was adopted in this research due to the fact that a large target population of students at the university could be broken down into small groups (strata) according to schools and year of study making it easy to view the different opinions. All the schools on campus were well represented using the study raosoft online calculator . For instance, the sample for school 1 was calculated as follows: (N1/N)*(n) for the school 1 where N1 is the population for the school and N is the total student population for the university and n is the required sample. Semi structured questionnaires were used as a data collection tool because of the many parameters that needed to be quantitatively analyzed. The questionnaire had both open and closed questions. The questionnaires were received in both hard copies and online copies.

3.3 *Data analysis*

Descriptive statistics were used to generate an overall picture of the data and participants. SPSS v 20 was used to process quantitative data to generate graphs and means. Microsoft excel Version 2019 was used to generate relative importance index. Construct reliability was measured using Cronbach alpha to determine internal consistency of the constructs in the study. The chi square test was used to determine the significance association between schools and quota application service in the SIS (McHugh 2013). Lastly the post hoc t test was used to analyse the familiarity on services between different groups. Relative importance index was predominantly used in understanding the relationship of the factors at the same time establish the most important and least important factors while critically analyzing both outcomes. The questionnaires were characterized by 5-point Likert scale with 5 being strongly agree and 1 being strongly disagree. The ranking system was used as seen in Table 1 to 6 in order to obtain factors that were more significant than the others in order to understand the strong and weak areas of the information system.

4 RESULTS AND DISCUSSION

The three hundred and sixty-seven constituted students in first, second, third, fourth and fifth year. A total of three hundred and twenty-two (322) responses were received from the targeted three hundred and sixty-seven (367) potential student respondents, which constitutes 88.2% response rate.

4.1 *Reliability*

Reliability is the measure of internal consistency of the constructs in the study. A construct is reliable if the Alpha (α) value is greater than 0.70 (Hair et al. 2013). In this study, construct reliability was assessed using Cronbach's Alpha Test. The results revealed that Q5i scale with eleven items ($\alpha = 0.873$), Q6i scale with eleven items ($\alpha = 0.840$) and Q10i scale with eighteen items ($\alpha = 0.903$) from the students' responses were found reliable.

4.2 *Evaluation of the efficacy of the SIS in meeting students and staff needs*

Relative Importance Index (RII) allows the identification of the most important criteria based on respondents' responses (Rooshdi et al. 2018). Relative Importance Index Formula is given as follows:

Relative Importance Index = 4n4+3n3+2n2+1n1
A*N Source: https://www.aidic.it/cet/18/63/026.pdf

n4 = Number of respondents for Very Familiar/Very Frequently/Very Often/Strongly Agree/Most Important
n3 = Number of respondents for Slightly Familiar/Frequently/Often/Agree/Important
n2 = Number of respondents for Familiar/Less Frequently/Less Often/Disagree/Less Important

Table 1. Frequently used services of the SIS by students.

Frequently Used Services	Relative Importance Index	Rank
Course Registration	0.6825	1
Examination Result Access	0.6662	2
Class Time Table	0.6638	3
Invoices	0.6630	4
Financial Statement	0.6310	5
Accommodation Application	0.6141	6
Examination Slip	0.5924	7
E-Learning	0.5761	8
Quota Application	0.4589	9
Policies	0.4216	10
Appeals	0.4022	11

Tables 1 and 2 shows the ranking of the services being offered by the SIS indicating what students and lecturers respectively frequently accessed. The findings revealed that the trend was not different with the familiarity one. The most frequently accessed service was the first six services being offered by the SIS with course registration, class timetable and invoices being the top three.

Table 2. Frequently used services of the SIS by lecturers.

Frequently Used Service	Relative Importance Index	Rank
Examination Results Access	0.8804	1
Course Registration	0.7826	2
Board of Examiners Reports	0.7717	3
Senate Reports	0.7391	4
Selection	0.7174	5
Curriculum	0.7174	6
Admissions	0.7065	7
Class Time Table	0.6848	8
Student Class Lists	0.6849	9
Exemptions	0.5978	10
E-Learning	0.5978	11
Appeals	0.5544	12
Quota Applications	0.4457	13
Policies	0.4348	14

Unfortunately, eLearning, access to policies and appeals were ranked low which is a major concern that requires immediate attention because eLearning is now a new concept that universities world over are adapting to continuity during pandemics such as COVID 19 and continuous support of physical learning. Interestingly, the first two most used services by students (Course registration and accessing examination results) were the same services that were selected by staff members.

4.3 *Devices used by staff and students*

Table 3. Devices used to by students to access SIS.

Gadgets Used to Access SIS	Relative Importance Index	Rank
Gadgets Used by students to Access SIS ON CAMPUS		
Smart Phones	0.9294	1
Laptops	0.5738	2
IPads/Tablets	0.3711	3
Personal Desktop Computers	0.3610	4
Computers in the University Laboratories	0.2826	5
Gadgets Used by students to Access SIS OFF CAMPUS		
Gadgets Used to Access SIS	Relative Importance Index	Rank
Smart Phones	0.9682	1
Laptops	0.5963	2
IPads/Tablets	0.3781	3
Personal Desktop Computers	0.3727	4

Tables 3 and 4 shows the ranking of the devices that student and lecturer respondents respectively prefer to use when accessing the SIS on campus. The findings revealed that the majority student respondents with RII 0.9294 access the SIS using their smart phones which was attributed to being convenient, with the least device/devices used being computers found in the university laboratories. This strongly suggests that the university needs to design a mobile application for ease of usage which at the moment is not available. This is one of the prominent indicators that came from this research. The popularity of mobile app usage is supported by results contained in a study by Wai et al. (2018).

Table 4. Devices used by staff members to access SIS.

Gadgets Used to Access SIS	Relative Importance Index	Rank
Gadgets Used by lecturers to Access SIS ON CAMPUS		
Laptops	0.9294	1
Personal Desktop Computers	0.5738	2
Smart Phones	0.3711	3
IPads/Tablets	0.3610	4
Computers in the University Laboratories	0.2826	5
Gadgets Used by lecturers to Access SIS OFF CAMPUS		
Gadgets Used to Access SIS	Relative Importance Index	Rank
Laptops	0.8804	1
Smart Phones	0.6522	2
Personal Desktop Computers	0.4348	3
IPads/Tablets	0.3913	4

There is need for the University to ensure that reliable WiFi provided to students is readily available and of good and consistent quality. The results further revealed that university desktop computers are old with low specifications and few making them unattractive for usage. The results for accessing SIS off campus is not different for students as seen in Table 3. This further means that remote access of the SIS must be enhanced for students though their mobile app and laptops. The difference in the ranking between smart phones and laptops was so significant 0.9294 against the next 0.5748 for laptops for on campus access. The results were not different for off campus access in terms of ranking variance between the first and second item. The laptop was the most common used platform on campus and off campus for staff members. This clearly demonstrates the different needs and priorities in terms of tools used to access the SIS between students and staff members. These results and challenges are similar to those from the study by Ocholla (2015) in Kenya.

4.4 *Statements about SIS*

Table 5. Student statements that are true about the SIS.

Statement that are true about the SIS	Relative Importance Index	Rank
System is slow due to congestion	0.8451	1
System is slow due to Internet Connectivity	0.7943	2
System is not regularly updated	0.7306	3
System displays accurate Information at all times	0.6289	4
System is too complex to use	0.4701	5
Password not recognised	0.4558	6

Tables 5 and 6 shows the ranking of the statements that students say to be true about the SIS, the ranking is presented in declining order with system is slow due to congestion and slow Internet connectivity ranking the highest while the least being password not recognized. There are low levels of system satisfaction by students. The results are consistent with Barret (1999) and Shah (2014) who stated the results of poor SIS that does not meet the needs of the stakeholders.

Table 6. Lecturers statements that are true about the SIS.

Statement that are true about the SIS	Relative Importance Index	Rank
System is slow due to Internet Connectivity	0.7283	1
System is slow due to congestion	0.7174	2
System is not regularly updated	0.6957	3
System displays accurate Information at all times	0.6304	4
System is too complex to use	0.4022	5
Password not recognized	0.3913	6

The number of users accessing the SIS at the time of data collection was more than the capacity of the initial intended users. This means that SIS is not meeting the students' needs as expected. The findings are consistent with studies done in the Philippines which highlighted that the system tended to be ineffective because the number of students on the system are more than the number considered when creating the system (Gamao and Rebortera 2018). The first three factors reflect a management responsibility which needs to invest in system upgrade. Results from Table 6 constitute strong evidence and feedback that pinpoints areas of weakness in the university's SIS. Regular updating of the SIS can be one of the measures that university can put in place to prevent system improve its efficiency (Breiter and Light 2008). The findings for staff members statements about SIS in Table 6 are not different from the students' statements in Table 5 proving strong consistency of the challenges in the SIS.

Table 7. ANOVA test for means of Devices/Devices used on campus.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.975	2	.988	4.646	.0130
Within Groups	84.601	398	.213		
Total	86.576	400			

Table 8. ANOVA test for means of Devices/Devices used off campus.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.340	2	.670	1.667	.190
Within Groups	159.939	398	.402		
Total	161.279	400			

Tables 7 and 8 shows the Analysis of Variance (ANOVA) Test conducted to test the devices/devices used to access the SIS on campus and off campus respectively. Results show a statistically significance difference in the devices/devices used to access the SIS between the three categories heads of departments/assistant deans ($p - value < 0.05$) and F-value = 4.646) between all the three categories of respondents. Students preferred using smart phones to access the SIS on campus while staff members and Heads of Departments/ Assistant Deans preferred using laptops. Further the table shoes analysis of Variance (ANOVA) Test was also conducted to test the devices used to access the SIS off campus as shown in Table 8. Result for devices used to access the SIS off campus show there is no significant difference ($p - value > 0.05$) and F-value = 1.667 between all the three categories of respondents.

5 PRACTICAL IMPLICATIONS

The construction industry has adopted BIM despite being at different levels in various countries. BIM will eventually become a requirement on many projects. It is therefore important that BIM be embedded in the training programs in higher education institutions to make construction related training programs relevant for current and future changes in the industry . Construction is a multi-disciplinary sector that requires many professionals to be conversant with BIM. The results from this study demonstrate weak footing in the SIS for embedding BIM training because BIM rides on a well-established, efficient and developed student information system which currently is too weak to adopt BIM in the training programs in the institution. The study strongly recommends investment in information systems that have high efficacy which forms a strong foundation for training in BIM related courses across the different programs in the schools. Some of the investment include high specification computers, reliable WIFI connectivity, retraining of staff members and purchasing of software licenses. While the study may have been based on a case study, many developing countries experience low investment in ICT practices related to infrastructure development. These results could therefore be extended to other higher learning institutions in developing countries who share common challenges in teaching environment and practices in relation to SIS and BIM adoption.

6 CONCLUSION

With the various issues raised during the study, the following are the conclusions based on the findings: Despite the number of challenges highlighted by users, they still considered the SIS acceptable based on the fact that it still met some of the significant basic requirements such as schools and departments being able to access services offered by the SIS according to their school and departmental needs. Factors that hinder the SIS from being effective include system being slow due to congestion and internet connectivity. The study concluded that the University had an SIS whose efficacy was low made worse by lack of regular system updates. Further, it was established that most students and staff members were not familiar with certain services offered by the SIS because they lacked knowledge about the service hence the recommended to the University introduce mandatory formal orientation/training program for new students to enable them gain knowledge on all the services offered by the SIS. The study recommends the development of a mobile application (APP) that will enable students and staff members have easy and quick access to the system. This is based on the fact that most students access SIS on the mobile phone and yet the SIS is not supported by any mobile application. Additional funding is required to the ICT Department to support system upgrade the SIS and other software whenever needs arises. This will further reduce congestion in the system leading to a more efficient SIS. Areas of research include providing technical specifications that would meet present and future projected SIS needs. With Building Information Modelling being the direction that training institutions and industry is taking, an effective SIS provides a good foundation and a prerequisite for adoption of BIM. With the weak SIS in place to accommodate BIM training, it is evident that the institution is not ready to fully adopt BIM unless investment is made to improve an SIS that will pave way for smooth adoption of BIM in training programs. This is because BIM has become an important tool in the delivery of infrastructure and development both in developed and developing countries.

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Factors hindering the adoption of virtual reality for construction workers' skills training in Zimbabwe

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ABSTRACT: Low construction workers' skills reduce construction labour productivity. Virtual reality (VR) has been touted as a pertinent intervention for upskilling. However, its utilisation has been affected by various factors. Hence, this research sought to determine the factors hindering virtual reality utilisation in training construction workers in Zimbabwe. A quantitative inquiry was undertaken through an online questionnaire survey of construction professionals in construction firms and lecturers from vocational training institutions. Factor analysis results revealed that organisational and training-related inadequacies, awareness and operational-related constraints, funding and management-related obstacles, and governmental policy and support-related inadequacies are affecting the utilisation of virtual reality in construction workers' training. Recommendations include engraving technology adoption in organisational policies and increasing investment in VR training institutions. A limitation of the study was the need for qualitative inquiry; however, further studies can implement a mixed-methods approach to enhance the study's validity.

Keywords: Virtual reality, Construction workers, Skills training, Zimbabwe

1 INTRODUCTION

Globally, the construction industry contributes 6% to the world's gross domestic product (GDP) (World Economic Forum 2016). In Zimbabwe, the construction industry plays a significant role as it contributes to the national GDP, which, according to *Zimstat* (2023), stood at 2.9% in 2021. Hence, construction skills remain vital for worldwide nations' productivity and economic sustenance (El Jazzar *et al.* 2021). The need for more skills among construction workers is prevalent and affects labour productivity in countries such as India (Mishra 2019) and the United States of America (Fenner *et al.* 2018). Skills and education levels significantly impact workers' performance (Karlsone and Ozola 2023). However, the increasing complexity of modern construction projects (El Jazzer *et al.* 2021) is increasingly exerting pressure on labour resources to meet productivity requirements. This problem is prevalent in Zimbabwe, and the lack of skilled and experienced labour has been identified as a critical factor affecting labour productivity (Moyo *et al.* 2023). Traditional training methods, such as factory schools and job instruction, have yet to fully close the skills gap (Fenner *et al.* 2018). The construction industry has struggled to make industrial improvements (Correa 2020), has lagged in technological advancement (Yousif *et al.* 2022), and needs to be more active in accepting new technology (Mishra 2019). Despite the advantages of modern technology, such as VR, over traditional training methods, several factors hinder

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the adoption of VR in construction workers' training (Selvaprasanth and Karthigaipriya 2021). However, the potential of VR to revolutionise construction management and worker training is immense, offering a promising future for the industry through better knowledge retention and engagement factors (Ghobadi and Sepasgozar 2020; Ventura *et al.* 2022). Therefore, this study sought to explore the underlying factors that affect the adoption of VR to address the skills shortage challenge. The study's specific objectives included determining the individual factors hindering the adoption of VR and establishing interrelationships among the significant factors. The following sections consider the theoretical background of construction skills training and explain the methodology. The results are presented, interpreted, and discussed. Finally, the conclusions and recommendations are presented.

2 LITERATURE REVIEW

2.1 *Construction workers' training during the fourth industrial revolution*

To enhance efficiency in production process and management, industries have developed from the eighteenth century through four revolutions (Osunsanmi *et al.* 2018). The current Industry 4.0 (4IR) originated in the automotive industry and is now being integrated into construction processes (Correa 2020). In the construction industry, gaps exist in how training should be delivered and for which trades (Fenner *et al.* 2018). There is an opportunity to improve construction skills through VR, highlighted as a critical industry 4.0 technology that can be utilised in construction worker skills training and upgrading (Ventura *et al.* 2022). Gawai and Dahane (2022) have outlined features that make VR ideal and effective as a training tool, including simulation and immersiveness through the participation of learners and workers in virtual buildings. They have further reported that these conditions provide safer training environments, more realistic training, endless repetition, increased trainee focus, customised learning material for specific sites and scenarios, and higher knowledge retention.

2.2 *Factors hindering the adoption of virtual reality in training construction workers*

A literature review revealed factors that hinder the adoption of VR, which are shown in Table 1.

Table 1. Summary of factors hindering the adoption of VR.

Code	Factors that hinder the adoption of VR	Sources(s)
VRB1	Complex nature of construction activities	Al Turk and Weheba (2022); El Jazzer *et al.* (2020)
VRB2	High investment requirements	Purushottam *et al.* (2020)
VRB3	Lack of awareness by management	Adepoju and Aigbavboa (2020)
VRB4	Lack of awareness of the potential benefits of VR	Bakhoum *et al.* (2023)
VRB5	Lack of back-end integrated systems	Bakhoum *et al.* (2023); Prabhakaran *et al.* (2023)
VRB6	Lack of electricity to support computer-based Technology	Adepoju and Aigbavboa (2020)
VRB7	Lack of expert knowledge in the construction industry	Selvaprasanth and Karthigaipriya (2021)
VRB8	Lack of government support	Adepoju and Aigbavboa (2020)
VRB9	Lack of government policy and law governing the adoption of VR	Al Turk and Weheba (2022); Du *et al.* (2022); Maqsoom *et al.* (2023)
VRB10	Lack of organisational policy on the adoption Usage of technology	Khudzari *et al.* (2023b); Yousif *et al.* (2022)
VRB11	Lack of organisational policy on workers' skills Development	Khudzari *et al.* (2023b)
VRB12	Lack of time to conduct training	Bakhoum *et al.* (2023); Maqsoom *et al.* (2023)
VRB13	Limited funding	Selvaprasanth and Karthigaipriya (2021)
VRB14	Resistance by management to adopting new Technology	Khudzari *et al.* (2023)
VRB15	Shortage of training skills	Adepoju and Aigbavboa (2020); Badamasi *et al.* (2021), Selvaprasanth and Karthigaipriya (2021)

Despite the advantages of VR over traditional training methods, impediments hinder the utilisation of VR. Construction projects are complex and heterogeneous (El Jazzar *et al.* 2020; Muhammad *et al.* 2020; Prabhakaran *et al.* 2022), resulting in demand for solid computer skills in the creation of equally robust dynamic virtual content (Haggard 2017), which translates to high content production costs. Programming of tailor-made content also demands the existence of solid back-end systems, which are, however, lacking within organisations (Muhammad *et al.* 2020). Further, experienced tutors are required to deliver lessons (Badamasi *et al.* 2021). However, there needs to be more competent personnel with adequate knowledge about how to set up and use the technology (Bakhoum *et al.* 2023).

In addition, the lack of resources has negatively impacted technology adoption. Resourcing problems include the cost of hardware and software programming (Badamasi *et al.* 2021) and a lack of electricity to support computer-based technology (Adepoju and Aigbavboa 2020). Further, more political support for VR implementation initiatives must be provided, especially in developing economies. Besides direct investments, government incentives such as tax cuts and free training programs (Khudzari *et al.* 2020a) can be critical drivers to the success of the adoption of technology (Maqsoom *et al.* 2023). Access to finance required to fund VR training activities is also limited (Adepoju and Aigbavboa 2020; Maqsoom *et al.* 2023), and thin margins together with a lack of return on investment (ROI) data have worsened the situation (Delgado *et al.* 2020).

The lack of stakeholders' awareness of the benefits of technology is also a challenge (Bakhoum *et al.* 2023). This is because the performance expectancy of technology drives its adoption (Ghobadi and Sepasgozar 2020). Thus, the management approach by top managers plays a crucial role in ensuring technology adoption (Khudzari *et al.* 2023b). Further, legal and policy issues (Al Turk and Weheba 2022), lack of regulations for data exchange (Maqsoom *et al.* 2023), and the absence of mandatory requirements for technology adoption (Du *et al.* 2022) have also been impeding factors. Further, lengthy training times required to grasp concepts and fully explore virtual reality are also challenging (Delgado *et al.* 2020; Khudzari *et al.* 2020a). Badamasi *et al.* (2021) have also posited that cultural changes are also an impediment to the implementation of VR.

Al Turk and Weheba (2022) used factor analysis to reveal six dimensions of barriers affecting 4IR adoption: security, social, technological, organisational, environmental, and economic. Further, Khudzari *et al.* (2023) have also used factor analysis to outline organisational resources, goals, and strategic plans as key underlying factors that affect the adoption of technology within organisations.

3 METHODOLOGY

This positivist study utilised a questionnaire survey to collect quantitative data, as supported by Salleh, Mustaffa, Rahiman, Ariffin, and Othman (2018), from lecturers working in training institutions and construction professionals working in building firms on the factors affecting the adoption of VR to address workers' skills challenges. All seventy-four (74) building firms are registered with the Construction Industry Federation of Zimbabwe (CIFOZ) category A to H and based in Harare and Bulawayo. All five training institutions based in Harare and Bulawayo and registered with the Ministry of Higher and Tertiary Education, Innovation, Science and Technology Development offering relevant construction skills training were considered for the survey: Bulawayo Polytechnic, Danhiko Industrial Training College, Harare Polytechnic, Msasa Industrial Training College and Westgate Industrial Training College. Harare and Bulawayo account for Zimbabwe's most registered training institutions and building firms (Moyo *et al.*, 2023). One training manager from each building firm and five lecturers from each training institution in the trades of bricklaying, plastering, plumbing, carpentry, and electrical were considered in the census. Thus, the target population was 99 respondents (seventy-four from building firms and twenty-five respondents from the five training institutions), and the expected response rate was 50% (50 responses). Chigara and Moyo (2022) and Maqsoom *et al.* (2023) deemed 29.6% and 56.36% adequate in similar quantitative studies.

The web-based questionnaire included two sections. The first section collected data on gender, age, work position, company operational experience, and highest educational qualifications. The second section had respondents rating the impact of the fifteen factors drawn from the literature on how they impact the adoption of virtual reality for construction skills training in Zimbabwe. A five-point Likert scale was adopted as used by Selvaprasanth and Karthigaipriya (2021), where 1 – very low impact; 2 – low impact; 3 – average impact; 4- high impact; 5 – very high impact. The data collection instrument was tested for reliability using Cronbach's Alpha, as used by a similar study (Selvaprasanth and Karthigaipriya 2021), with a minimum threshold of 0.70 to indicate internal consistency (Hair *et al.* 2010). The fifteen (15) factors were tested for reliability and yielded a Cronbach's alpha of 0.952, indicating high internal consistency and reliability of the data.

The data was first analysed using mean scores (MSs) to identify the most impactful factors. Factors with mean values above the midpoint were impactful. The midpoint was calculated using the scale (1+2+3+4+5)/5 = 3, adapted from Chigara and Moyo (2022). The standard deviation was used to separate factors with the same mean and assign a higher rank to the factor with the lowest standard deviation, as Khudzari *et al.* (2023b) used. Factor analysis was used to reveal the underlying factors affecting the adoption of virtual reality. The Kaiser-Myer-Olkin (KMO) test, as well as Bartlett's Test for sphericity, was carried out to measure the adequacy of the data for factor analysis. KMO coefficients of values ≥ 0.70 and p-values < 0.05 are considered significant (Lloret *et al.* 2017) as they show that the correlation matrix is factorable. Exploratory factor analysis was used to reduce the number of variables and reveal correlations and homogeneity between the fifteen factors (Delgado *et al.* 2020). Factor loadings for each component were rotated using the varimax rotation method for simplicity to get more meaning (Watkins 2018). Factors with eigenvalues greater than one are retained, while those with fewer than one are disregarded (Hair *et al.* 2010). Naming the components or groups of factors is usually informed by the highest item in each group (Chigara and Moyo 2022; Onsunsanmi *et al.* 2018). Factors scores were used to rank the underlying factors affecting VR adoption. Factors with the highest value got the highest ranking from first to last, as guided by Hair *et al.* (2010).

4 RESULTS AND DISCUSSION

4.1 *Survey response rate and demographics*

Ninety-nine questionnaires were emailed to building contractors and TVET Centers via email, and 62 responses were received, translating to a combined 62.63% response rate. A similar quantitative study utilising a census by Chigara and Moyo (2022) in the same study area, Harare and Bulawayo, yielded a response rate of 29.6%, which was found to be adequate. The demographic profile of respondents is presented in Table 2. The table shows the demographic characteristics, description, frequency, and percentage frequency. The results show that all trades offered in colleges were represented in the survey, with carpentry having the most responses (35.71%). Most of the responses (25.81%) were obtained from the most experienced workers (> 20 years). The results also potentially show that critical managerial and lecturing positions are occupied chiefly by professionals with Bachelor's degrees (56.45%). Overall, all respondents had the relevant qualifications and knowledge about training issues, which ensured the validity of the data.

Table 2. Demographic profile of respondents.

Characteristic	Description	Frequency	Percent (%)
Nature of organisation	Building firms	48	77.42
	Technical & Vocational Institutions	14	22.58
	Total	62	100.00
Respondents' designation	Lecturer	14	22.58
	Site Agent/Manager/Training Manager	48	77.42
	Total	62	100.00
Represented trades offered in training institutions	Bricklaying	3	21.43
	Carpentry	5	35.71
	Electrical	2	14.29
	Plastering	2	14.29
	Plumbing	2	14.29
	Total	14	100.00
Respondent Work experience	0 – 5 years	15	24.19
	6 – 10 years	13	20.97
	11 – 15 years	13	20.97
	16 – 20 years	5	8.06
	> 20 years	16	25.81
	Total	62	100.00
Educational background	Doctor of Philosophy	3	4.84
	Master's Degree	11	17.74
	Bachelor's Degree	35	56.45
	Diploma	10	16.13
	Certificate	3	4.84
	Total	62	100.00

4.2 *Factors hindering the adoption of virtual reality to enhance construction workers' skills*

Respondents were asked to rate the impact of fifteen factors selected from the literature review that significantly hindered the adoption of virtual reality to enhance construction workers' skills in Zimbabwe.

4.2.1 *Mean ranking of the factors affecting the adoption of virtual reality utilisation*

Table 3 presents the mean scores and ranks for the factors. It also shows each barrier's sample size and standard deviation values. All fifteen factors have a mean score greater than the midpoint score of 3.00, indicating that respondents view all the factors as having a major as opposed to a minor effect on adopting virtual reality to enhance construction workers' skills. The top three factors included limited funding, lack of government policy and law governing the adoption of virtual reality, and lack of organisational policy on adopting and using technology. In Nigeria, limited access to funding was found to significantly affect the adoption of 4IR technology (Adepoju and Aigbavboa 2020). Du *et al.* (2022) also outlined a lack of government policy and mandatory measures as critical external third-party factors hindering technology adoption. Khudzari *et al.* (2023) have underpinned organisational policy as a critical factor that affects technology adoption within organisational structures. The respondents deem limited funding and lack of governmental policy and law governing the adoption of VR as the most impactful factors having a high to a very high impact / high impact on VR adoption and utilisation with MSs $> 4.20 \geq 5.0$ and ranked first and second respectively.

Table 3. Factors hindering the adoption of virtual reality.

Factors hindering the adoption of virtual reality	N	Mean	Standard Deviation	Rank
VRB13 - Limited funding	62	4.29	1.246	1
VRB9 - Lack of government policy and law governing the adoption of virtual reality	62	4.29	1.165	2
VRB10 - Lack of organisational policy on the adoption and usage of technology	62	4.10	1.224	3
VRB11 - Lack of organisational policy on workers' skills development	62	4.03	1.254	4
VRB8 - Lack of government support	62	4.03	1.116	5
VRB7 - Lack of expert knowledge in the construction industry	62	4.00	1.159	6
VRB – 15 Shortage of training skills	62	3.97	1.116	7
VRB3 - Lack of awareness by management	62	3.97	1.024	8
VRB2 - High investment requirements	62	3.95	1.122	9
VRB14 - Resistance by management to adopting new technology	62	3.92	1.297	10
VRB4 - Lack of awareness of the potential benefits of virtual reality	62	3.84	1.059	11
VRB5 - Lack of back-end integrated systems	62	3.65	1.118	12
VRB12 - Lack of time to conduct training	62	3.52	1.388	13
VRB6 - Lack of electricity to support computer-based technology	62	3.32	1.364	14
VRB1 - Complex nature of the construction industry	62	3.29	1.260	15

Factors ranked from 3rd to 13th had MSs $> 3.20 \leq 4.20$, indicating a moderate to high impact / high impact on VR adoption. Lastly, factors ranked 14th and 15th have MSs $> 2.60 \leq 3.40$, indicating a low impact to moderate impact on adopting virtual reality in training.

4.2.2 *Relationships among factors*

The results in Table 4 revealed four (4) unique underlying factors affecting the adoption of virtual reality to enhance workers' skills in Zimbabwe. The table shows the factors affecting VR adoption, the factor loadings for each variable under the different components, and the reliability and score for each factor. It also shows the Eigenvalues for each component and the total variance. The KMO coefficient was 0.827, and Bartlett's test of sphericity was significant p = 0.001, suggesting the data was adequate for factor analysis. The factors with eigenvalues greater than 1 explained 73.07% of the total variance. The 1st component had an eigenvalue of 6.794, while the 2nd component had an eigenvalue of 1.467. The third and fourth had eigenvalues of 1.394 and 1.305, respectively. The factors are discussed hereafter.

Table 4. Results of factor analysis.

	Component					
Factors hindering the adoption of virtual	1	2	3	4	Reliability	Factor scores
Factor 1- Organisational & Training-related					*0.787*	*1.271*
VRB10 -Lack of organisational policy on the adoption and usage of technology	0.854					
VRB12 -Lack of time to conduct training	0.838					
VRB15 -Shortage of training skills	0.829					
VRB11 -Lack of organisational policy on workers' skills development	0821					

(*continued*)

Table 4. Continued

Factors hindering the adoption of virtual	Component 1	2	3	4	Reliability	Factor scores
VRB14 -Resistance by management to adopt technology	0.790					
VRB7 -Lack of expert knowledge in the Construction industry	0.561					
Factor 2 - Awareness & Operational-related					*0.978*	*1.588*
VRB5 -Lack of back-end integrated systems		0.851				
VRB4 -Lack of awareness of potential benefits of virtual reality		0.670				
VRB6 -Lack of electricity to conduct training		0.667				
Factor 3 - Funding & Management -related					*0.796*	*1.404*
VRB2 -High investment requirements			0.872			
VRB3 -Lack of awareness by management			0.575			
VRB13 -Limited funding			0.514			
Factor 4 - Governmental & Support-related					*0.901*	*2.172*
VRB9 -Lack of government policy and law governing adoption and usage of VR				0.698		
VRB8 -Lack of government support				0.690		
VRB1 -Complex nature of construction activities				0.619		
Eigenvalues	6.794	1.467	1.394	1.305		
Cumulative variance	45.296	55.076	64.368	73.228		

4.2.2.1 *Component 1: Organisational & training – related factors* The 1st factor was named *'organisational and training–related factors',* explained by 45.296% of the total variance. This factor accounted for six variables: lack of organisational policy on the adoption and usage of technology (VRB10), lack of time to conduct a training (VRB12), shortage of training skills (VRB15), lack of organisational policy on workers' skills development (VRB11), resistance by management to adopting new technology (VRB14) and lack of expert knowledge in the construction industry (VRB7). The six variables had a reliability of 0.787, indicating good reliability, and the factor was ranked 4th with a component score of 1.271. This factor highlights that organisations lack a vision for technology adoption by top and middle-level managers/ lecturers. The results collaborate with previous studies (Adepoju and Aigbavboa 2020; El Jazzer *et al.* 2020) where organisations do not have policy guiding technology adoption and lack the skills required to conduct technology-based training (Badamasi *et al.* 2021). This can be detrimental to the entire organisation as these managers/ lecturers are responsible for formulating, administering, and diffusion human resource management policies to the rest of the workers/trainees within the organisation. This is further buttressed by Khudzari *et al.* (2023b), where management within organisational structures is a critical success factor affecting technology adoption.

4.2.2.2 *Component 2: Awareness & operational–related factors* The 2nd factor was named *'awareness and operational–related factors'*, which was explained by 9.781% of the total variance. Three variables loaded this factor: lack of back-end integrated systems (VRB5), lack of awareness of the potential benefits of virtual reality (VRB4), and lack of electricity to conduct training (VRB6). The variables had an excellent reliability of 0.978, and the factor was ranked 2nd with a component score of 1.588. The constituents show that the stakeholders are not significantly aware of the availability of virtual reality as a tool to enhance construction workers' skills, as observed by Onsunsanmi *et al.* (2018), and there are also operational challenges (Haggard 2017). However, the results are inconsistent with observations by Ghobadi and Sepasgozar (2020), where stakeholders were aware of the situation but were found to be reluctant to provide operational support due to an inherent nature within construction professionals to resist new technology. In developing countries, the technology is still relatively new, coupled with electricity supply challenges (Adepoju and Aigbavboa 2020) as well as a lack of programmed learning material (Prabhakaran *et al.* 2022) due to the complex and dynamic nature of the construction industry which produces heterogeneous products (Muhammad *et al.* 2020).

4.2.2.3 *Component 3: Funding and management – related factors* The 3rd factor was named *'funding and management–related factors'*, explained by a variance of 9.292%, and was loaded by three (3) variables: high investment requirements (VRB2), lack of awareness by management (VRB3), and limited funding (VRB13). The three (3) variables had a good reliability of 0.796, and the factor was ranked 3rd with a component score of 1.404. The results correspond with other observations (Adepoju and Aigbavboa 2020; Jazzer *et al.* 2020; Khudzari *et al.* 2023b; Selvaprasanth and Karthigaipriya 2021) that have pointed out high investments as a significant limiting factor to technology adoption within organisations. In developed economies, investments have reached billions of dollars (Purushottam *et al.* 2020). The hardware and software plus programming experts are the pillars of VR implementation, and the financial resources required to purchase such are scarce as there are other competing needs. This significantly affects any efforts by stakeholders to implement VR.

4.2.2.4 *Component 4: Governmental policy & support – related factors* The 4th factor was named *'governmental policy and support-related factors*. Three (3) variables loaded this factor: lack of government policy and law governing the adoption of virtual reality (VRB9), lack of government support (VRB8), and the complex nature of construction activities (VRB1). This factor was ranked second (1st) with the highest component score of 2.172. The government plays a vital role in formulating and implementing national policies. Further, it also has the political power and duty required to establish laws and policies that govern technology adoption. In developed countries, governments view training as crucial, and it has become a global currency of the twenty-first century (Elgar 2013). Governments in those economies shape policy on VR adoption and usage. However, the rampant lack of support from the most influential stakeholders greatly hinders any efforts at technology adoption. Construction projects also tend to be heterogeneous, demanding unique requirements (Prabhakaran *et al.* 2022). This exerts pressure on experts to continuously upgrade training content continuously, thus raising content production costs and further hindering the adoption of the technology for upskilling.

5 CONCLUSION AND RECOMMENDATIONS

Low labour productivity due to a lack of skills is prevalent in Zimbabwe. The study aimed to explore factors affecting the adoption of VR to enhance construction workers' skills in Zimbabwe. Mean score ranking results showed that limited funding and lack of governmental policy law governing the adoption of VR have a very high impact on VR adoption and utilisation. The bottom two factors affecting VR utilisation are the lack of electricity to support computer-based technology and the complex nature of the construction industry. Factor analysis revealed four underlying factors that affect the adoption and utilisation of VR in construction worker training in Zimbabwe. These include organisational and training-related, awareness and operational-related, funding and management-related, and governmental and support-related factors. The study results have some practical policy implications. Firstly, there is a need for an organised framework for continuous upskilling in VR among construction company training managers and college lecturers. Secondly, there is a need for planned periodic collaborative awareness workshops to enhance knowledge, attractiveness, and acceptability of VR. Thirdly, the Ministry of Finance & Economic Development in Zimbabwe is recommended to provide special funding for VR hardware and software through direct investments, tax incentives, and grants in training centres. Lastly, there is a need for mandatory regulations on VR adoption in government training centres and government-administered incentives for adopting VR within private companies to enhance its spread. A limitation of the study was the need for a qualitative inquiry. Future studies should utilise qualitative methods to gather in-depth insights from trainers and other construction-related professionals towards VR adoption to enhance the study's validity.

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Theme 11: Land, project management & capacity development

Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

The challenges of implementing Public-Private Partnership (PPP) for infrastructure projects in low-income countries: A case study of Malawi

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ABSTRACT: The Malawian government has faced significant challenges in infrastructure delivery due to financial constraints. Recently, there has been a shift towards Public-Private Partnerships (PPP), which has shown the potential to address the infrastructure deficit. However, adopting PPP in most low-income nations has faced some peculiar constraints, resulting in slow uptake. A systematic literature review was conducted on the current research trends from Malawi and seven other low-income countries between 2010-2023, using Scopus and Google Scholar databases. The result identifies difficulties in securing credits from financial institutions, low political commitment, lack of transparency and competitiveness in the procurement process, and lack of technical and managerial expertise, among others, as the critical challenges in implementing PPP infrastructure projects in Malawi. The study further categorised these challenges into themes and proposed strategies to overcome them. The findings provide stakeholders with actionable insights for successful PPP implementation through overcoming the prevailing PPP challenges.

Keywords: Public-Private Partnership, Infrastructure Projects, Challenges, Implementation, Low-income Countries

1 INTRODUCTION

Finance has posed a significant challenge to governments across many nations of the world, translating into truncated efforts in infrastructure project delivery. These challenges are particularly predominant in Low-Income Countries (LICs), where infrastructure deficits persist amidst increasing urbanisation and rising poverty levels (Shendy *et al.* 2011). In Malawi, infrastructure delivery predominantly relies on public sector and donor funding, each contributing approximately $40 million annually. However, to bridge the significant infrastructure gap, an estimated yearly expenditure of $0.6 billion is required (Foster and Shkaratan 2010). In addressing this funding deficit, there has been a recent shift in the approach to infrastructure delivery, moving away from conventional methods and embracing Public-Private Partnership (PPP). The World Bank defines PPPs as a long-term contract between a private partner and a government entity that involves a public asset or service (Trebilcock and Rosenstock 2015). Similarly, Bwanali and Rwelamila (2016) describe PPP as an innovative approach to financing and procuring infrastructure. Through this model, private actors provide capital, technical skills, and innovation to infrastructure projects, effectively addressing the resource constraints often encountered by governments. Moreover, Ozioma *et al.* (2020) emphasised that LICs seeking to boost their economic diversity and growth must prioritise the PPP approach for funding infrastructural development. This approach enables the prompt delivery of essential public facilities and equips nations to handle complex economic situations by efficiently distributing risks and rewards. Mourgues and Kingombe (2017) highlighted that adopting PPP demonstrates a strategic dedication to fostering sustainable economic progress and mobilising the collective capabilities required to overcome the intricate challenges of modern infrastructure development. Beckett-Camarata (2020) also added that this approach could serve various purposes, including modifying, expanding, or rehabilitating existing infrastructure and even monetising underperforming infrastructure to generate capital for the government. Despite its potential benefits, PPP in most developing countries has experienced a slow uptake and has been implemented in very few infrastructure projects (Bwanali and Rwelamila 2016; Yang *et al.* 2013). As a result, existing literature (Almeile *et al.* 2022; Kwofie *et al.* 2019; Wang *et al.* 2020) has extensively examined the various challenges contributing to the poor performance of PPP in developing countries. However, some authors (Almeile *et al.* 2022; Chileshe and Kavishe 2023; Osei-Kyei and Chan 2019) have noted a limitation in the generalisation of the studies due to their focus on specific countries. This narrow scope fails to consider the unique social and economic contexts of different developing countries, thereby limiting the practical applicability of their findings. Moreover, while previous studies (Ahmadabadi and Heravi 2019; Muhammad and Johar 2019) have attempted to identify and classify PPP success factors, there has been limited effort to systematically identify and categorise PPP challenges. Therefore, this review seeks to bridge these significant gaps and provide stakeholders with actionable insights for successful PPP implementation.

This paper aims to identify the critical challenges associated with implementing PPP for infrastructure projects in low-income countries by comprehensively analysing a diverse set of literature. It attempts to explore the context of Malawi and other low-income countries to identify the prevailing challenges, categorise them into broader themes and propose strategic interventions to address them effectively. This provides critical insights for future PPP projects and enhancement of infrastructure development.

This paper is organised into four main sections. Following this introduction, section 2 briefly discusses the methodological approach to the systematic review and provides an overview of the results from the reviewed literature. Section 3 examines the categorisation and discussion of the identified challenges based on themes. Finally, section 4 presents the conclusions of the review.

2 METHODOLOGY

This research employs a systematic literature review to explore the challenges of implementing PPP in Malawi and various other LICs to deepen the comprehension of these challenges and their implications. Systematic reviews involve a well-defined approach to collecting, analysing and interpreting all available academic contributions on a specific research topic in an unbiased and repeatable way (von Danwitz 2018; Rowe 2014). The choice of this approach can be attributed to its prominence in recent research studies on PPP (Jayasena *et al.* 2021; Le *et al.* 2022; Rasheed *et al.* 2022; Zhang *et al.* 2020). Additionally, this approach is characterised by the precise and predefined approach taken toward literature selection, data extraction, and analysis, ultimately strengthening the reliability and validity of the findings. The systematic review process involves three broad procedures (Narbaev 2022).

2.1 *Identification*

The first step entails conducting a comprehensive search of academic database engines to identify the relevant works of literature to be included in the study. The Scopus and Google Scholar search databases were chosen because they are among the largest abstract and citation databases of peer-reviewed and non-peer-reviewed scientific journals (Babalola *et al.* 2019). Harzing and Alakangas (2016) also agreed that Scopus and Google Scholar provide more comprehensive coverage than other significant databases like the Web of Science.

Hence, this study focused on research papers from Scopus and Google Scholar. Additionally, these databases have been employed in recent systematic reviews on PPP (such as (Almeile *et al.* 2022; Le *et al.* 2022; Rasheed *et al.* 2022; Zhang *et al.* 2020). Initially, for the pre-search, the acronym PPP was used, resulting in a limited number of articles. It is believed that PPP has variant references in literature. Lambert and Lapsley (2006) mentioned that 'Private Finance Initiatives', PFI is one of the variant references of PPP. Additionally, studies with the words 'construction' and 'risk' expanding to the full text and abstract were considered to meet the requirements of this study. In order to ensure a comprehensive search, articles with these specific terms were found to have a relationship with PPP in the title, abstract, or keywords. Thus, the articles were retrieved from Scopus and Google Scholar using search terms "Challenges" OR "Risk" AND "Public" AND "Private" AND "Partnership" OR "PPP" OR "Private" AND "Finance" AND "Initiatives" OR "PFI" AND "Infrastructure" OR "Construction".

2.2 *Screening*

The second step involves establishing inclusion and exclusion criteria to ensure the relevance and consistency of the chosen studies (Rutter *et al.* 2010). The inclusion criteria encompass published works in English, full-text publications, and publications between 2010-2023, primarily emphasising PPP challenges in Malawi and other LICs. Articles with duplications were excluded by screening the titles of the publications. A total of 1054 articles were extracted from the various databases. 400 were removed because they included duplicates and papers lacking open access online. 574 papers were further screened out because they either lacked a peer review process, were not written in English or did not focus on PPP in Malawi or LICs, leaving 80 studies. The abstracts of the 80 studies were assessed, excluding 63 articles, as the articles did not focus on the challenges of PPP implementation for infrastructure projects. Seventeen papers were selected for the concluding analysis. The systematic process is shown in Figure 1.

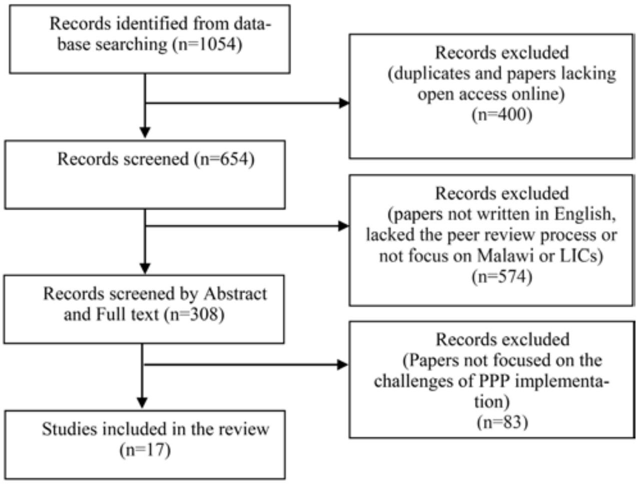

Figure 1. Flow chart showing systematic literature review.

2.3 *Findings result*

Thematic analysis was employed to synthesise the study findings and extract relevant information from the results. An inductive approach was adopted to identify inherent themes and subthemes in the dataset by closely examining the data and allowing patterns and commonalities to surface organically (Rybnicek *et al.* 2020). This section presents the descriptive analysis of the geographical coverage of the selected studies (Table 1) and an overview of the challenges of PPP identified from the selected studies (Table 2).

Table 1. Country classification per publication.

Country	Number of publications
Malawi	4
Bangladesh	2
Tanzania	2
Zambia	2
Ethiopia	2
Uganda	2
Afghanistan	2
Lesotho	1

Table 2. Challenges of implementing PPP for infrastructure projects.

CHALLENGES	REFERENCES
Difficulties in securing credits from financial institutions	Bayat *et al.* (2019); Belachew and Shyamasundar (2013); karimi and Piroozfar (2015); Manase and Sukasuka (2016); Makoza (2021); Mugarura *et al.* (2020); Rashed *et al.* (2014); Zulu *et al.* (2023); Venkatesan (2016)
Lack of transparency and competitiveness in the procurement process	Alinaitwe (2012); Bayat *et al.* (2019); Hellowell (2019); Gordon (2012); Kavishe and An (2016); Karimi and Piroozfar (2015); Marson and Maggi (2017); Rashed *et al.* (2014)
Lack of technical and managerial expertise in the public sector	Alinaitwe (2012); Chileshe *et al.* (2023); Hellowell (2019); Gebru *et al.* (2022); Kavishe and An (2016); Makoza (2021); Mugarura *et al.* (2020); Rashed *et al.* (2014); Venkatesan (2016)
Inadequate enabling environment in terms of legal, regulatory and institutional frameworks	Alinaitwe (2012); Gordon (2012); Gebru *et al.* (2022); Marson and Maggi (2017); Karimi and Piroozfar (2015); Makoza (2021); Kavishe and An (2016); Venkatesan (2016)
Low political commitment	Alinaitwe (2012); Bayat *et al.* (2019); Chileshe *et al.* (2023); Gordon (2012); Kavishe and An (2016); Manase and Sukasuka (2016); Makoza (2021); Zulu *et al.* (2023)
Weak capacity of the public sector	Zulu *et al.* (2023); Mugarura *et al.* (2020); Alinaitwe (2012); Karimi and Piroozfar (2015); Bayat *et al.* (2019); Hellowell (2019); Gebru *et al.* (2022)
Delays in project approval	Kavishe and An (2016); Mugarura *et al.* (2020); Hellowell (2019); Zulu *et al.* (2023)
High costs of project development	Alinaitwe (2012); Kavishe and An (2016); Manase and Sukasuka (2016); Marson and Maggi (2017); Mugarura *et al.* (2020)
Lack of access to long-term loans	Gebru *et al.* (2022); Hellowell (2019); Manase and Sukasuka (2016); Mugarura *et al.* (2020)
Inconsistent and unclear PPP policy	Alinaitwe (2012); Gebru *et al.* (2022); Makoza (2021); Zulu *et al.* (2023)
Common lack of clarity on the roles of public and private sectors	Manase and Sukasuka (2016); Makoza (2021); Mugarura *et al.* (2020)
Public resentment of privatisation	Bayat *et al.* (2019); Marson and Maggi (2017); Makoza (2021)
Unstable government	Gordon (2012); Manase and Sukasuka (2016)

3 THEMATIC ANALYSIS

In this section, the findings of this study are synthesised into themes that provide a comprehensive and coherent view of the several challenges to implementing PPP for infrastructure projects in LICs. These themes include legal and regulatory, financial, social, political, and cultural challenges.

3.1 *Legal and regulatory challenges*

The challenges reported under the legal and regulatory challenges include an inadequate enabling environment in terms of legal, regulatory and institutional frameworks, inconsistent and unclear PPP Policy and lack of clarity on the roles of public and private sectors. The absence of a clear legal and regulatory framework can hinder collaboration between the public and private sectors in PPP projects (Mugarura *et al.* 2020). Even if a project agreement is well-drafted, it may be unenforceable or irrelevant if it conflicts with the country's existing laws and regulations. Therefore, the government's sole responsibility is to enact comprehensive legislation and regulations on PPP (Nwangwu 2012). In cases where there is an existing PPP legislation, reforms may be necessary to align with the regulatory context. For instance, establishing an institutional structure to ensure compliance and guide stakeholders involved in PPP creates a more robust legal and regulatory environment for successful PPP implementation (Li *et al.* 2017).

3.2 *Financial challenges*

This theme highlighted difficulties in securing credits from financial institutions, lack of access to long-term loans, and high project development costs. PPP projects often rely on a significant private finance component involving equity and debt financing. Equity investors, who assume higher risk, expect more significant returns on their investment, making PPPs more expensive. Additionally, securing long-term loans from private investors or financial institutions remains costly, with interest rates ranging from 7% to 25% (Manase and Sukasuka 2016). These challenges significantly influence the financial decisions of PPP projects. Exploring innovative financing mechanisms, such as business term loans or infrastructure funds, can inject fresh capital into PPP projects (Khmel and Zhao 2016). Furthermore, governments should provide sovereign guarantees and incentives to concessionaires for critical infrastructure, facilitating fund-raising efforts (Tokiwa and Queiroz 2015).

3.3 *Social challenges*

The challenges identified under this theme include resentment by the public and the lack of transparency and competitiveness in the procurement process. When the local community resists a PPP project, it may indicate their lack of cooperation, possibly due to concerns about its impact on the community. Also, the issue of corruption and lack of transparency undermines the integrity of the procurement process, leading to limited participation of qualified and capable stakeholders, inflated projects, and compromised infrastructure quality. Robust community consultation and participatory decision-making processes foster trust and reduce resistance. Additionally, encouraging competitive bidding procedures and improving procurement practices can create a fair environment for all involved parties (Zhang and Chen 2013).

3.4 *Political challenges*

The challenges identified under this theme are unstable government and low political commitment. A frequent change in leadership through a democratic process, coups or civil unrest disrupts policy continuity, undermines investor confidence, and affects the implementation of PPP (Manase and Sukasuka 2016). For instance, Zulu *et al.* (2023) highlighted that change in government has led to the renegotiation or cancellation of some existing PPP contracts in Zambia, causing delays and uncertainties. Moreover, without strong commitments to prioritise long-term infrastructure, political leaders will only focus on short-term gains or face pressure from interest groups, hindering the development of robust PPP frameworks. Policymakers must prioritise PPP as a strategic tool for sustainable development backed by consistent leadership and clear policies (Verhoest *et al.* 2015).

3.5 *Cultural challenges*

The cultural challenges identified include a lack of technical and managerial expertise in the public sector, weak capacity of the public sector, and delays in project approval. Public organisations in most LICs are majorly known for their bureaucratic structure, characterised by hierarchical decision-making procedures. This mainly results in a complex flow of information that prevents private investors from partnering with the public sector. Also, the process of planning, designing, constructing and operating PPP infrastructure projects requires skilled and experienced personnel. The public sector in LICs has a record of a high shortage of technical and managerial experts required to effectively negotiate and execute PPP arrangements, leading to suboptimal contract terms and project delivery. A robust coordination system like Building Information Modeling (BIM) can enhance institutional capabilities, simplify administrative procedures, and encourage collaboration and knowledge sharing with private sector counterparts (Ganah and John 2013). Moreover, training can help develop the essential capacity to plan, execute, and oversee PPP projects efficiently, promoting successful infrastructure development (Umar *et al.* 2019).

4 CONCLUSIONS

Due to the widespread appeal of PPP in research and adoption for infrastructure project delivery, this review was undertaken to contribute to the body of knowledge on the challenges of implementing PPP for infrastructure projects from the perspectives of LICs. The results of this review identified and categorised critical challenges to successful PPP implementation, including legal and regulatory, financial, social, political and cultural challenges. To address these challenges, the study recommends that governments and political actors demonstrate strong commitment by enacting robust legislation and endorsing PPP initiatives. Additionally, providing sovereign guarantees to the private sector for critical infrastructure can facilitate fundraising efforts. Also, ensuring a participatory decision-making process and promoting competitive bidding can address the issue of trust and transparency. Lastly, implementing a robust coordination system (such as Building Information Modeling - BIM) and offering continuous training to agencies are essential to enhance institutional capabilities. Practically, the outcome of this study provides decision-makers and stakeholders with actionable insights for successful PPP implementation. Despite this study contributing to the literature on the challenges of PPP in LICs, certain critical studies might have escaped the author's attention. This may be partly due to the complex nature of the term 'PPP'. However, the analysed critical challenges identified in this study can be further explored for future research.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Implementation of stakeholder cooperation on road construction projects in Zimbabwe. A case of Harare-Beitbridge highway

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ABSTRACT: This study was prompted by inadequate stakeholder cooperation which is hampering the successful execution of road projects in Zimbabwe. Using a case study of Harare – Beitbridge highway construction, 50 questionnaires were administered, and 30 responses were received with key stakeholders to probe the implementation and impediments to stakeholder cooperation. Statistical analysis of collected data indicated the inconsistent application of the generic stakeholder engagement process whilst inadequate funds, poor consultation, unclear communication channels, and uncontrolled project variations were the major impediments to effective stakeholder cooperation. Therefore, effective stakeholder cooperation is mainly influenced by communication-related factors. The study recommends the use of communication platforms such as BIM to enhance stakeholder cooperation. Although the case study design limits the generalisability of findings, the results provide insights to policymakers, government, and other key stakeholders to develop measures that improve stakeholder cooperation to improve the success of highway projects.

Keywords: Stakeholder cooperation, Impediments, Roads projects, Highway projects, Construction industry

1 INTRODUCTION

Rahman, Radzi, Saad and Doh (2019) defined highway projects as projects that are public roads that connect cities and towns. Highway projects have a major impact on the economy and society (Rahman *et al.* 2019). The latter scholars further argue that the success or failure of highway projects depends on the cooperation of key project stakeholders. Essentially, the authors emphasise effective collaboration of stakeholders as cardinal in stimulating the successful execution of highway projects. This is corroborated by Ankukumah (2016) who posit that it is important to incorporate all key stakeholders during project implementation to attain best results. This stems from the fact that the construction of highway projects worldwide is marred by a myriad of challenges which are largely attributed to ineffective stakeholder cooperation (Karimi and Piroozfar 2022; Rajeev and Kothai 2014). According to Sampieto (2016), project stakeholders can change the project processes and activities which ultimately mitigate eventualities which project managers might not have predicted, hence positively impacting project success. Rashid, Bhat and Bahsir (2017) demonstrate that highways which pass through mountainous, earthquake, landslides, and frost prone areas

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like Kashmir region in India could only succeed if key stakeholders are extensively consulted and incorporated into the construction process.

Zimbabwe is one of the countries in Southern Africa which is undertaking mega national highway projects to catalyse its economic growth. However, as argued by Karimi and Piroozfar (2022), these projects are characterised by *numerous* challenges which include land acquisition squabbles, inaccurate designs and bills of quantities, corruption in the procurement process, insufficient contractors' experience, progress payment delays by the client, poor qualifications of contractors and shortage of equipment and materials. It appears that most of these challenges are directly linked to the lack of stakeholder cooperation in highway construction in Zimbabwe. There is a dearth of literature on the impediments of stakeholder cooperation in this context. Therefore, the study sought to assess the impediments and drivers of stakeholder cooperation on highway construction projects in Zimbabwe in a bid to improve efficient delivery of these projects. The study employed the case of Harare-Beitbridge Highway. The results of the study have potential to assist government, policymakers and other key stakeholders involved in the implementation of highway projects to develop an effective stakeholder management process which could spur efficient and effective delivery of highway construction projects in Zimbabwe and similar contexts. Thus, the paper contributes to the conference theme related to sustainability in infrastructure development.

2 STAKEHOLDER COOPERATION ON HIGHWAY PROJECTS

2.1 *Challenges to stakeholder cooperation*

Stakeholder management is an important and common practice in any project as it facilitates better process management, performance, and risk (Zwikael *et al.* 2012). Challenges can be viewed as chances for success rather than problems for projects to be completed successfully (Adner 2006). Effective project management necessitates the ability to manage uncertainty and deal with a variety of challenges as viewed by Andersen and Svejvig (2015). Rahman and Singh (2022) also pointed out that ineffective stakeholder engagement significantly contribute to construction projects cost overruns which resulted into project failure therefore it was then noted that stakeholder issues must be handled as emergencies to avoid projects cost overruns. Bourne (2016) added by stating that effective stakeholder engagement benefits project performance by eliminating conflicts and reducing costs through increased stakeholder participation in projects decision making. The findings were also echoed by (Dacha and Juma 2018) who observed that, stakeholders need to be effectively engaged in construction projects procurement processes in order to avoid cost overruns which may come in form of delays. Afunanya, Achoru and Williams (2016) stated that cost overruns being reported in the construction industry of Nigeria have continued to hinder performance improvement of various construction projects. Afunanya *et al.* (2016) noted that affected projects were characterized by disputes of which further investigations revealed that whenever interest and expectations of key stakeholders were not taken into consideration that has always been the case. It was also noted in the study by Mwanaumo and Mambwe (2019) that once stakeholders are engaged on a project, the risk of accidents, incidents and fatalities on site is reduced, thus mitigation of poor scheduling that could arise from lost time. According to Mambwe *et al.* (2020), it was the contractor's actions of expressing unwillingness or delays towards the projects which in-turn resulted into increased cost overruns. On the other hand, Chilongo and Mbetwa (2017) study on factors contributing to construction project failure in Lusaka District in Zambia revealed that effective engagement of stakeholders namely, Contractors, Consultants and Client was cardinal thereby contributing more to the development of the construction project. It was thus important to note that effective stakeholder engagement influenced construction project outcomes.

2.2 *Driver of stakeholder cooperation*

The project's goals and efficient execution would be at risk if stakeholders' interests are not met (Von Meding *et al.* 2013) hence a need to engage stakeholder cooperation practices. Effective stakeholder cooperation depends on communication, openness to ideas, suggestions and complaints, identifying and mapping stakeholders, as well as transparency.

2.2.1 *Stakeholder engagement*

Stakeholder engagement is explained as a process of ensuring that all individuals, groups, or institutions affected or maybe affected by the project outcome take part in project planning and decision-making determinations to include their expectations and needs (Talley *et al.* 2016). Einur *et al.* (2016) noted that early stakeholder engagement on most construction projects in New Zealand was identified to be the main contributor of efficiency and effectiveness in project performance. Additionally, in Australia, Heravi, Coffey and Trigunarsyah (2015) highlighted that contractor involvement tends to be low just when the project starts, thus resulting into low performance. It was stated that to overcome this, there was a need to consider contractors early in the project by possibly employing a unified project conveyance approach. Rahman *et al.* (2022) added that the construction industry has many different stakeholders and engaging them ensures that a project gets the best out of every stakeholder. However, it is neither easy nor required to engage with every one of them equally and similarly (Rahman *et al.* 2022). Therefore, the engagement will be determined by the role they play, and their power and interest they have in the project.

2.2.2 *Effective communication*

Julia (2016) highlighted that continuous communication with all project stakeholders, the more they understand the rationale behind the project's plan. Additionally, the author posited that effective communication flow allows participants to voice their personal concerns which in turn allows all stakeholders especially the public engagement team more control over the topics of discussion at each during the execution of the project. Siew, Balatbat and Carmichael (2013) added that communication is the most essential stakeholder cooperation practice in collective attempts to achieve construction project goals. Von Meding *et al.* (2013) supported and added that it is important to keep the lines of communication open to involve stakeholders in mutual understanding. This discourse allows participants to share opinions and come to consensus on cultural structures, actions, and events. Wijntjes (2023) noted that communicating transparently only works if it is done regularly, clearly, and concisely. This helps you get the message across and keep your stakeholders happy. Windapo (2014) supported the idea of communication as a way of engaging stakeholders. Some companies are taking this a stage further and using the internet as part of a stakeholder engagement strategy involving dynamic interaction as expectations regarding the roles of companies with respect to their stakeholder's change. Good communication does not only involve sending out a message; a large part of it is also listening to the responses that you get.

2.2.3 *Openness to ideas, suggestions, and complaints*

Chilongo and Mbetwa (2017) argued that stakeholder's management can not only be achieved through communication but there is need for rigorous debate which helps to discover truth, increases knowledge, exposes the reasoning processes, and facilitates the formulation of correct choices and policies. Openness to ideas, suggestions and complaints is also a stakeholder management practice that can be used to manage stakeholders towards enhancing social sustainability (Wijntjes 2023). Gutterman (2023) concurs that engagement implies understanding stakeholders' views and taking them into consideration, being accountable to stakeholders when accountability is called for and using the information gleaned from them to drive innovation.

2.2.4 *Identifying and mapping stakeholders*

Identifying and mapping all the stakeholders and communities that are relevant and influential for a project. Tools such as stakeholder analysis matrices, power-interest grids, or social network analysis to categorize stakeholders according to their level of interest, influence, impact, and relationship with the project can be used. Xia *et al.* (2015) mentioned that successful management of stakeholders ensures to engage them properly via actively giving them support and working together to devise, plan and develop new business solutions. Stakeholder mapping can be adopted as a technique that allows the engagement of stakeholders. Wijntjes (2023), noted that project stakeholders cannot be managed properly without first creating a stakeholder map. The map shows stakeholder relationships to each other. Due to the complexity of relationships, one decision making can cause stakeholders' various reactions, and the project manager should balance the interests of the entire stakeholder set (Yang 2019). Windapo (2014) proposed stakeholder circle, to map stakeholders to provide a useful and effective way to visualize stakeholder power and influence that may have pivotal impact on a project's success or failure.

2.2.5 *Transparency*

Transparency was also noted by Wijntjes (2023), as a stakeholder management practice. Wijntjes further noted that transparency can be appreciated so much more than secrecy by every single one of project stakeholders. Franklin (2020) adds that the values that can be produced from stakeholder interactions include transparency. Crane (2020) posit that transparency is fundamental to good stakeholder engagement and partnership building. Precisely, transparency provides the foundation for ensuring that stakeholders feel valued and treated fairly. According to Yitmen, Erkul and Cerlic (2016), two-way communication provides a platform for information flow between stakeholders and the main purpose is to gain a transparent decision-making process with greater input and feedback and this improves project concept and design and reduce conflicts.

3 METHODOLOGY

This study adopted a quantitative approach to collect data using a self-administered questionnaire survey instrument. According to Soiferman (2010) quantitative methodology was adopted as it allows the researcher to test theories deductively from existing knowledge, by developing hypothesized relationships and proposed outcomes for study. The target population for this study was derived from Ministry of Transport and Infrastructure development, The government (Zimbabwe National Roads Administration, Zimbabwe Republic Police), contactors, members of the local community and bus companies and regular road users. The study was confined to the case of Harare-Beitbridge Highway which is currently under construction. Due to time and financial constraints the researcher carried out a cross sectional survey as advised by Saunders and Bezzina (2015). 50 questionnaires were administered to the respondents by hand and through emails, and 30 questionnaires returned. According to Cooper and Schindler (2014) self-administered survey questionnaire enabled the researcher to achieve less cost, sample accessibility, efficiency in time, anomaly, and topic coverage. Relative Importance Index, Severity Index and mean score were employed to analyse the data.

4 RESULTS

4.1 *Response rate*

50 questionnaires were administered and 30 were returned. Kothari and Garg (2014) mention that a response rate of 50% is adequate for analysis and reporting of data therefore a rate of 60% is good and a response rate of 72% and over is excellent; therefore, the response rates for this study was 60% which is deemed good and adequate for the analysis.

4.2 *Demographic information of respondents*

Table 1 presents the respondents' demographic information regarding gender, age and educational qualifications.

Table 1. Demographic information of respondents.

Category		Frequency	Percentage
Gender	Male	20	67
	Female	10	33
	Total	30	100
Age	18-25	1	3
	26-35	12	40
	36-45	13	44
	46-55	3	10
	55+	1	3
	Total	30	100
Education qualification	National certificate	1	3
	Diploma	7	24
	Bachelor's Degree	14	47
	Master's Degree	7	23
	Doctorate	1	3
Total	30	100	

As shown on Table 1, gender distribution indicates that the construction industry is male dominated as most respondents are males, representing 67%, and the remaining 33% being female. On the age group, the majority respondents are aged between 36 to 45, represented by 44%. This is followed by respondents between 26 to 35, represented by 40%, while the remaining 16% of the respondents are between 18 to 25 and above 55 years of age. Regarding educational qualifications, most respondents are bachelor's degree holders, represented by 47%. This is followed by diploma holders with 24% and master's degree holders with 23%. The remaining respondents are doctorate holders, represented by 3% and national certificate with 3%.

4.3 *Impediments of stakeholder cooperation on highway projects in Zimbabwe*

Table 2 below show the impediments the of stakeholder cooperation on highway projects in Zimbabwe. Respondents rated each issue on a scale of 1 to 5, 1 being strongly disagree and 5 being the most relevant issue. From Table 2, it is indicated that the major impediments of stakeholder cooperation in order of severity include lack of communication, with a mean of 4.6, limited resources, with a mean of 4.3, political interference, with a mean of 4.1 and conflicting interests, with a mean of 3.8.

Table 2. Impediments of stakeholder cooperation.

Impediment	N	Mean	SI	Rank
Lack of communication	30	4.6	0.92	1
Limited resources	30	4.3	0.86	2
Political interference	30	4.1	0.83	3
Conflicting interests	30	3.8	0.76	4
Valid N (listwise)	30			

4.4 *Drivers of stakeholder cooperation on highway projects in Zimbabwe*

Table 3 shown below shows the drivers of stakeholder cooperation. Respondents rated these aspects on a Likert scale of 1 to 5, where 1 means not important 5 means extremely important.

Table 3. Drivers of stakeholder cooperation.

Driver	N	Mean	RII	Rank
Establishing Communication channels	30	4.4	0.89	1
Analysis of stakeholder interests and concerns	30	4.2	0.8	2
Promoting collaborative decision making	30	4.1	0.83	3
Creation of comprehensive stakeholder map	30	3.9	0.78	4
Monitoring Stakeholder Satisfaction	30	3.9	0.79	5
Developing of Stakeholder profiles	30	3.8	0.76	6
Establishing Clear conflict resolution process	30	3.5	0.7	7

The results of the study showed that the top five drivers of stakeholder include the establishing communication channels with a mean of 4.4 and RII of 0.89, analysis of stakeholder interests and concerns, with a mean of 4.2 and RII of 0.8, promoting collaborative decision making with a mean score of 4.1 and RII of 8.3, creation of comprehensive stakeholder map, with a mean of 3.9 and RII of 0.78 and monitoring stakeholder satisfaction, with a mean 3.9 and RII of 0.79.

5 DISCUSSION OF RESULTS

The study revealed that the major impediment of stakeholder cooperation on highway projects in Zimbabwe is lack of communication. Most respondents rated the factor as the most severe in impeding stakeholder cooperation on highway projects. The findings align with Obonadhuze *et al.* (2021) who attest that a lot of failures and poor project performances reported on construction projects have been blamed on communication. However, Rauzana (2016) assert that conflicts are the major impediment that arise on highway projects due to scarce resources. Rauzana's sentiments are partly supported by the findings of the study which rated the factor as fourth placed, with a mean score of 3.8 and severity index of 0.76. The low rating suggests that, although conflicts negatively impact stakeholder cooperation on construction projects in Zimbabwe, they are less severe compared to lack of communication, political interference and limited resources which were ranked 1, 2 and 3 respectively. Despite the study having found limited resources as a major impediment, the respondents did not acknowledge scarce resources as the major cause of conflicts on highway projects. Political interference which was found by the study as a major impediment with a mean of 4.1 is consistent with extant literature. Lehne *et al.* (2018) assert that political interference raises the cost of highways. This aligns with the sentiments of most respondents who highlighted that political interference is rampant in the Zimbabwean context which often results in project abandonment or costly projects. To ameliorate the identified impediments, the five major drivers proposed by the study which include establishment of communication channels, analysis of stakeholder interests and concerns, promoting collaborative decision making, creation of comprehensive stakeholder map and monitoring stakeholder satisfaction are corroborated by a plethora of studies (Rahman *et al.* 2022; Wijntjes 2023; Yang 2019). For instance, Panjaitan *et al.* (2023) argues that communication channels serve to inform stakeholders of crucial updates and vital information. As such, establishing communication channels, stakeholder engagement and embracing other mentioned strategies have potential to improve the success of highway projects in Zimbabwe.

5 CONCLUSION

This paper examined the impediments and drivers of stakeholder cooperation in highway projects in Zimbabwe. Based on the findings of the study, the study concludes that factors like lack of communication, limited resources, political interference, and conflicting interests are the major impediments of stakeholder cooperation on highway projects in Zimbabwe. These aspects stifle the smooth implementation of highway projects, resulting in costly delays, abandonment, or cost overruns. Thus, to promote effective stakeholder cooperation, improvement of communication should be initiated through coming up with initiatives to bridge communication gaps. Also, there is a dire need for regular stakeholder meetings or improved reporting systems. The research also indicated that conflict resolution strategies are to be set in place and develop strategies which could include stakeholder engagement programs or negotiation training. The research findings show an anomaly in the use of resources therefore resource management must be enacted to curb the issue of limited resources through optimizing resource allocation and exploring alternative resources. Engagement with political entities to minimize interference, possibly through advocacy or forming strategic alliances to reduce political interference is essential to stakeholder cooperation success. The results of the could assist key stakeholders involved in highway projects to develop strategies that improve their cooperation which culminates in improved project success in Zimbabwe. Additionally, policymakers could utilise the results to improve stakeholder management policies to enhance delivery of highway projects in Zimbabwe and similar contexts, particularly in the Global South. Although the results provide valuable insights, the geographical delimitation employed in the study, which confined data collection to the case of Harare-Beitbridge highway, precludes the findings from being generalised without caution. Therefore, further research can broaden the scope of the study by exploring more highways under construction in Zimbabwe or other countries in the Sub-Saharan Africa.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Project and management scope factors influencing the selection of contract procurement method in the Kwazulu Natal construction industry

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ABSTRACT: The criteria for selection of procurement methods in the construction industry is crucial to the successful delivery of the project. A study of kwazulu-Natal province, South Africa was undertaken. The target population of the study were professionals in the construction field, the Architects, Project managers, Quantity surveyors, Engineers and Contractors, A sample of 65 professionals was surveyed, and data was analyzed using discrete analysis methods. The reliability of this study was confirmed using a Cronbach alpha coefficient of 0.70. Findings for this study are, scope of the project, budgeted project, size of a project, project quality management and project risk management are factors that influence the selection of a procurement strategy on project delivery. The study recommends that among the factors to be considered for the selection of a procurement method, scope of the project, budgeted project, size of the project, quality and risk plans should be the foremost.

Keywords: Management scope, Procurement method, Project management, Project delivery, Project scope

1 INTRODUCTION

Every institution needs a procurement system that is within the legislative frame work, fair, equitable, transparent and cost effective. Morledge *et al.* (2021) opined that the efficient procurement of construction work through the effective procurement strategy is one of the major determinants of success or failure of project delivery. Thwala and Mathonsi (2012) further noted that the right procurement system is important in ensuring the successful execution of construction projects in all the phases of any particular project. South Africa as a developing country faces a quite number of socio-economic challenges which influence the South African construction industry (Oshungade 2015); hence construction projects objectives are rarely met due to these socio-economic challenges as clients tend to get accustomed to and stick with a “traditional procurement” approach that frequently fails to address the requirements and sensitivities specific to a particular project type (Mbanjwa 2004). In other words, there is a definite need to establish a certain project requirement for an effective procurement method that best addresses the demand of such project.

According to Jeselski and Talukhaba (1998) construction contract procurement evolved in South Africa in 1994 when the south African ministry identified a pressing need for public sector procurement reform regarding construction projects. After an initial review of the regulatory environment that influenced procurement systems, it was decided that the reform could not be embarked upon on a sector by sector basis since an essential review of the entire public-sector procurement system was required.

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The procurement systems being employed for construction projects must be analysed critically and intensively with clear differentiation identified between the traditional and non-traditional approaches and variations as such, for clients to have a more astute understanding for selecting an effective procurement approach that suit each specific project need.

As mentioned, the introduction of different 'fast-tracking' contract procurement strategies is the attempt by the industry to provide more alluring deals to clients seeking, quite understandably, the best value for money' out of projects in term of cost, time and quality (Masterman 2003).

This study aims to identify the most effective project and management scope factors for contract procurement strategies for project delivery towards enhancement of construction project sustainability in KwaZulu Natal, South Africa. By identifying and addressing these factors, this study will contribute to the advancement of procurement strategy in the construction industry and the South African country as a whole.

2 LITERATURE REVIEW

2.1 *Project scope factors influencing selection of a contract procurement strategy on project delivery*

2.1.1 *Size of the project*

A project size is one of the project's physical appearance. There are different things to note while classifying a project based on size such as the number of months it would take to get executed, the risks involved, skills required, number of professionals and stakeholders involved and sub project if there is any. The size of a project is a ranked factor which influence the selection of contract procurement for a project (Akudoro *et al.* 2021).

2.1.2 *Scope of the project*

Effective scope management have a positive impact on other key areas of a project such as time, cost and quality. A project scope involves a work breakdown structure which is the hierarchical constituents of a project. The scope of a project consist of the initiation, planning, definition, verification and change control (Khan 2006). Professionals involved in projects are advised to prepare a plan that would reduce changing in design scope which can lead to cost and time overrun. The Architects and Quantity surveyors are mainly charged with this responsibility (Adegoke *et al.* 2019).

2.1.3 *Nature of the project*

Nature of the project is in relation to the identification and description of the works to be performed. Project could be residential, Industrial or commercial. The nature of project could also be defined in terms of size and complexity as large, medium and small. A nature of a project should dictate the overall goal of the project (Adegoke *et al.* 2019).

2.1.4 *Type of the project*

According to Alhazmi and McCaffer (2000) the type of a project is a characteristics that affect project performance. The characteristics of a project that overrun construction duration and cost is classified into weather, cost data, experience, design changes, labour productivity and resources changes (Zaman *et al.* 2022).

2.1.5 *Site conditions*

Site conditions refers to the physical conditions on or under the site and its near surroundings. It includes artificial things and latent conditions and it includes weather conditions. Gidado (2001) noted that site and ground investigation has to be done thoroughly before a procurement strategy is selected. A site must be readily accessible, have enough storage space, and be well secured and safe.

2.1.6 *Budgeted project*

Refers to the plan that details how much you will spend for what and by when. Budget plan of a project are done in advance to monitor spending funds for the entire period of the project. It is essential that there is enough allotment of asset. Capital budgeting and procurement processes has to be robust and incentives that could undermine the pursuit of value for money should be minimized. A weak integration of project planning and ex ante value-for-money assessment with the budgeting process may cause projected and realized value for money to deviate (Burger and Hawkesworth 2013).

2.1.7 *Project quality*

Project quality depends on strength of materials, durability of the product, workmanship and the aesthetic view of the product of the project. It can be said that quality is how close the product comes to meet the beneficiaries needs. Quality of project are the most influencing factor for the use of management oriented method of procurement while speed and responsibility had little influence on its selection (Adegoke *et al.* 2019).

2.2 *Management scope factors influencing selection of a contract procurement strategy on project delivery*

2.2.1 *Project management*

The practice of using knowledge, skills, tools and techniques to complete series of tasks to deliver value and achieve a desired outcome is project management. A project success is not caused by one influential factor but by a number of interrelated factors. A performance management system constructed with multi-dimensional and multi-observational project management KPI such as cost, quality, health and safety could be one of a project's success (Bryde and Brown 2004).

2.2.2 *Project quality management*

The process of continually measuring the quality of activities and taking corrective action until the team achieves the desired quality is project quality management. Quality management process assist in controlling the cost of a project, therefore in quality management standards are established and steps to achieve these standards are developed. Project quality management are divided into two parts which are informal quality management system and formal quality management system. Project quality management includes the processes to combine organization quality policy that includes quality management plan, quality management maintenance and quality management control. These also support improvement activity processes that is as sustainable as the organization that carried it (Okifitriana and Latief 2021).

2.2.3 *Project risk management*

Project risk management is the process of identifying, anticipating, mitigating, preventing, and responding to potential risk event that may occur during a project being undertaken. There are benefits and risks of introducing new management methods (Bryde and Brown 2004). Project risk management depends on the tools and techniques available, how the available tools are used and procedures that follows, attitudes of people in the organization (Ökmen *et al.* 2024).

2.2.4 *Project organisation structures*

Project organization structure is a tool that indicates the hierarchy of people, their function, workflow, and reporting system. This assists in guiding and defining the way which organization carries on its operations. The construction manager and the other stakeholders that are involved in procurement decision making of an organization needs to formulate a systematic selection approach as this would help in the project structure and assist in eliminating unnecessary project demand (Mathonsi and Thwala 2012).

2.2.5 *Adequate project monitoring*

A project is well monitored when it is tracked and evaluated constantly so as to examine any risk or issue and adjusting plans if there is a need. Monitoring a project regularly enables the project to stay on track and meet deadlines. This also involves meetings of stakeholders and also constant visit to project sites to review its progress. All stakeholders must understand and commit to the required new ways of working to meet all the element of performance used by the performance management system (Bryde and Brown 2004).

2.2.6 *Effective cost management*

Cost management is a process of planning, controlling and monitoring the cost of a project to ensure that the resources available are effectively and efficiently allocated, effective cost management involves cost estimation, budgeting, cost control, resource optimization and continuous improvement. Cost management requires a deep understanding of a firm's cost structure (Hansen *et al.* 1997).

2.2.7 *Technical skills of the project leader*

The project leader is the architect of a project's success, the project leader needs to have personal capabilities such as technical and professional expertise, problem solving skills and being innovative. interpersonal skills such as the ability to communicate prolifically, the ability to inspire and motivate others to high performance, management and leadership skill in addition to his technical skills would ensure a smooth delivery and success of a project (Pandya 2014).

2.2.8 *Efficient time management*

An effective time management is needed in construction projects. A project manager is needed to plan construction projects. A labour allocation plan is needed and progress of projects are to be reported as whole and update the schedule monthly. Schedules are updated by preferring the schedule as a straight, date-related status line and the work actually done to the left of the line while the work yet to be done on the right and the schedule re-sequences. This would show the effect upon timing of the remaining planned activities of the progress estimated to have been achieved to date (Chin and Hamid 2015).

3 RESEARCH METHODOLOGY

A questionnaire survey was conducted for this study. A total of sixty five (65) questionnaires were administered to construction professionals (Architects, consultant Quantity surveyors, contracting Quantity surveyors, project managers, contractors and others) in KwaZulu Natal Province. Forty five (45) questionnaires were administered in person to the respondents, out of which thirty one (31) questionnaires were duly completed and retrieved. The remaining questionnaires were administered via electronic email.

The respondents in the study held different positions in various firms. The participants' firms include Contracting firms (19.61%), Architectural firms (11.76%), Project management firms (21.57%), Quantity surveying firms (9.80%),client (13.73%) and Engineering firms (17.47%). Most of the respondents have Bachelor's degree qualification (45.1%), Honours (17.65%). The average years of experience of respondents is 11-15 years and most of the respondents have worked for both public and private organisations. The first section of the questionnaire dealt with the respondents general information, the second section comprises sub sections that addresses the objective of the research with the aim of examining the perception of respondents on the effectiveness of contract procurement strategies and also factors influencing the selection of a suitable procurement method.

The data was analyzed using discrete analysis method. Simple statistical tools such as the mean score and standard deviation were used for the statistical analysis of data. Based on the result of the analysis of data, conclusion and recommendation were drawn. Hence, the respondents were able to provide valid and reliable information based on the knowledge acquired from different firms.

4 DATA PRESENTATION AND ANALYSIS

Table 1. Project scope related factors that influence the selection of a contract procurement strategy on project delivery.

S/N	Factor	Mean score	Standard Deviation	Rank
1	Scope of the project	4.83	0.270	1
2	Budgeted project	4.72	0.190	2
3	Size of the project	4.54	0.164	3
4	Project quality	4.46	0.151	4
5	Nature of the project	4.43	0.148	5
6	Type of the project	4.37	0.139	6
7	Site conditions	3.93	0.074	7

Table 1 presents project scope factors that influence the type of procurement method for a project. Scope of the project has the highest mean score (MS = 4.83) amongst project scope related factors that influence the selection of a contract procurement strategy. A complex project scope may require a procurement strategy which is collaborative and enable all project stakeholders to work together. The project scope needs to be defined at the project onset and procurement strategy needs to be well aligned to the design scope.

Next to project scope is budgeted project (MS = 4.72). Budgeted projects implies that it has a budget plan, this determines the availability of resources on site. if a project is likely to fail, budget plan should be one of the criteria set out in the selection of procurement method. A project which has more budgeted cost would enable flexibility and choice of a suitable procurement plan while a project which has a slim budget will restrict the available options.

Size of a project (MS = 4.54) is another project related factor which influences the selection of contract procurement method. A smaller project requires a simpler procurement strategy while a larger project might need a complex and solid procurement strategy.

The second to the least ranked factor amongst the project scope factors that influence the selection of procurement options is the Type of project (MS = 4.37). The type of project, whether small or large, complex or simple, the duration required for delivery are parameters that are known and for this reason it does not have major influence on the selection of procurement method of a project.

Site condition (MS = 3.93) is considered as the least important factor that influence procurement strategy selection. All projects sites are subject to have few or many of the site conditions features which includes trees, ducts, service cables and adjoining building. These need to be either taken away or repositioned on site, therefore the reason for its rating. The layout and available utilities and infrastructure are also part of the conditions to be looked out for.

Table 2. Project management related factor that influence the selection of a contract procurement strategy on project delivery.

S/N	Factor	Mean	S.D	Ranking
1.	Efficient time management	4.85	0.397	1
2	Project quality management	4.70	0.323	2
3	Project risk management (seen and unforeseen)	4.46	0.288	3
4	Adequate project monitoring	4.22	0.253	4
5	Effective cost management	4.15	0.243	5
6	Project organisation structure	3.76	0.185	6
7	Technical skills of the project team leader	3.28	0.115	7
8.	Project scope management	3.24	0.108	8

Table 2 reveals project management factors that influence the selection of procurement strategies. Efficient time management (MS =4.85) is considered a very important management factor as it has an impact on project timelines, deadlines and also a project success. The choice of procurement depends on the time constraint involved in the project.

Project quality management.(MS = 4.70) is another factor needed to be considered before selecting contract procurement strategy, the choice of a procurement strategy is needed to support the goals of the project quality.

Project risk management (MS = 4.46) is ranked third amongst the project management factors to be considered for type of procurement option. The amount of risk involved in the procurement of the project will indicate the procurement option. Some projects are complex and involving a lot of risk, it may be due to its difficulty of building and introduction of new materials and facilities. Project risk management allows for risks to be weighed and then a tailored procurement strategy to the risk mitigation is selected.

The second to the least ranked factor is Technical skills of the project team leader (MS = 3.28). Technical skills of the team leader indicates the experience of the team leader to deliver project as planned. It reflects the success story of the leader. A project leader in most cases are chosen based on their track record, particularly on large projects, they are certified before engagement. Therefore, the reason this factor is rated as such.

The least factor among the project management factors influencing the selection of the procurement method is Project scope management (MS = 3.24). Project scope management is about the volume of work to be executed in a project. The BOQ and the specifications in relation to structures and other provisions to be incorporated in the project defines its scope. It is based on those that tenders are made and does not really affect the procurement strategy. This being whether the project is a joint venture, public – private and so on. These may be the likely reason it is rated least among the project management factors that influence the procurement strategy for a project.

5 DISCUSSIONS

The study findings on project scope factors influencing contract procurement selection strategy which is budgeted project aligns with Afriyie (2015) findings that the estimated value of a project has a strong influence on method of procurement to be selected for a project. Further, the study of Bolumole (2017) on contract procurement strategy for project delivery towards enhancement of housing sustainability in South Africa also agrees that the adoption of a right procurement strategy would avoid excessive project cost, time overrun and low project quality.

Hashim *et al.* (2006) listed the most common criteria that influences the choice of procurement method, amongst these factors is time which aligns with the study finding that efficient time management on project management construct influences the selection of a contract procurement strategy on project delivery. The study finding in relation to size of the project as a factor that influences the selection of a contract procurement strategy aligns with Mathonsi and Thwala (2012) findings that project characteristics whose variable are size and technical complexity of the project influences the life cycle of the project.

6 CONCLUSIONS

From the study findings the following conclusions are reached. From the project scope factors, scope of the project, budgeted project, size of a project are amongst the project scope factors most influencing the selection of a contract procurement strategy in relation to project delivery. Regarding project management factors, efficient time management, project quality management and project risk management are the project management related factors that most influence the selection of a procurement strategy in project delivery.

The recommendations for this study are, scope of the project, budgeted project, size of the project, quality and risk plans should be the foremost factors that should be considered in the selection of a procurement strategy relative to project delivery.

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Perspective on risk factors in build-operate-transfer student housing infrastructure development: A scientometric analysis

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ABSTRACT: Using scientometric analysis, this paper examines studies on risk factors in build-operate-transfer (BOT) projects related to student housing infrastructure from 1994 to 2024. Bibliometric data was obtained from Scopus and Dimensions AI, and 38 relevant articles were selected. The analysis revealed a consistent increase in research on risk factor in BOT for other project types since 2007, but few in student housing. Most articles originated from China, Australia, the UK, and the USA. The numerical analysis of 22 authors of the 38 selected articles indicated 162.8 as an average score of the total research link strength. Through the chosen articles, keywords such as risk assessment, critical risk factors, critical success factors, and risk mitigation were identified alongside various BOT project types. Few key terms related to student housing infrastructure suggest insufficient attention. The study concluded on the need to encourage research on risk factors in BOT student housing development.

Keywords: public-private partnership/build-operate-transfer projects, projects risk, infrastructure development, student housing, scientometric analysis

1 INTRODUCTION

Build-operate-transfer (BOT) is a public-private partnership (PPP) arrangement that involves procurement of public infrastructure including educational facilities. This model is being used to close academic facility gaps occurred due to a lack of government funding (Osei-Kyei *et al.* 2022). BOT student housing involves a private investor building and operating student housing for a set time before transferring it to the educational institution (Oyeyoade and Araloyin 2019). BOT reduces pressure on institution resources and allowing focus on academic and research roles.

Despite the advantages of BOT, some risks may deter private investors in student housing. Private investors aim to minimize risks for expected returns, while the public sector aims to avoid failed infrastructure due to risks. Research on risk mitigation strategies could encourage PPP involvement in student housing development.

Generally, risk in BOT has motivated various studies. The main themes studied include risk management, assessment, identification, classification, allocation, critical risk and success factors (Fu *et al.* 2023; Song *et al.* 2016). Research on BOT concession projects mainly focus on understanding and mitigating risk factors for the successful delivery and operation of projects like toll roads, airports, waste management, and water schemes (Chan *et al.* 2010; Li *et al.* 2005; Osei-Kyei *et al.* 2022), with slight attention to student housing and educational infrastructures. This implies that investors in BOT student housing are vulnerable to the scarcity of relevant information on peculiar investment risks.

This paper therefore focuses on examining risk factors in BOT student housing infrastructure using data from past studies. The aim is to assess the extent of research in this domain with a view to enhancing research efforts on student housing development. The

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objective is to analyse journal publications from 1994 to 2024 on risk factors in BOT projects, identify leading journal outlets, determines the most productive country in publishing articles, and reviews previous studies on risk factors in BOT infrastructure development to understand the prevalence of BOT student housing in research.

The review will inform researchers about BOT risk studies, promote offshore research collaborations, and suggest ways to present research on student housing infrastructure development. It will also offer a flexible background for stakeholders to understand risk factors in BOT student housing development.

2 METHODOLOGY

This study uses a scientometric analysis to summarize previous studies on BOT risk factors. The scientometric analysis allows for an in-depth investigation of previous studies (Fu *et al.* 2023; Song *et al.* 2016; Wuni *et al.* 2019). The research procedure is divided into three levels, and the methodology design involves four stages (Figure 1).

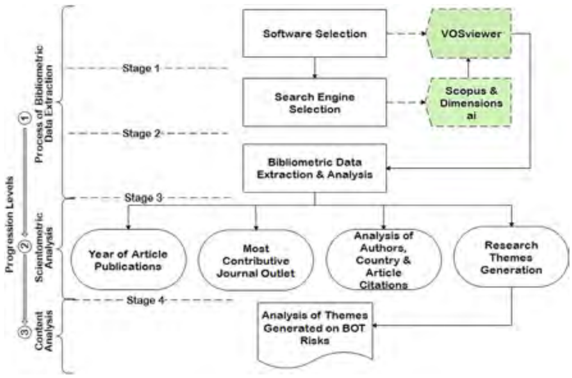

Figure 1. Flowchart of methodology. *Sources*: Authors' adaptation (2024).

2.1 *Software selection*

The first step in the initial process is choosing exploratory software for scientometric analysis. Researchers like Jin *et al.* (2019); Wuni *et al.* (2019) and Osei-Kyei *et al.* (2022) commonly use VOSviewer for bibliometric data mining. Therefore, this study opts for VOSviewer to achieve its objective.

2.2 *Search engines selection*

Scopus database was chosen for its reliability in journal indexing (Osei-Kyei and Chan 2015). The research also utilized Dimensions AI for data collection. Dimensions AI provided broad information on relevant articles and cross-checking of results from VOSviewer application.

2.3 *Bibliometric data collection and article selection*

At the second stage of the first level, bibliometric data were extracted from Scopus and Dimensions AI. The search terms used include risk, risk factors, risk management, risk assessment, risk mitigation, PPP, BOT project types, CRFs, CSFs, etc. By indication, 2,566 articles were primarily retrieved from 194 publication outlets, from which 614 articles from 12 journal publishers were isolated for further assessment that produced 38 relevant articles selected for this study. The topics of the selected articles span through methods of risk identification in PPP, risk allocation among the PPP stakeholders, tendering procedure in PPP, and criteria for selecting private investors for PPP contract arrangement, among others.

2.4 *Scientometric analysis*

The second level involves the third stage of research, including scientometric analysis of bibliometric data. VOSviewer was used for analysis through visualized map networks and tables. The findings include journal outlets, article's country of origin, co-citations, co-authorship, and research themes on BOT risk factors.

2.5 *Analysis of article contents*

Last, the third level of the research method centred on the fourth stage where compatible themes are collated for analysis and methodical review in line with the strength of argument presented by the authors of the selected articles.

3 FINDINGS AND DISCUSSION

The findings and discussion mainly centred on 38 selected articles focusing on risk factors in PPP/BOT. The findings show that the articles used various BOT project types as case studies, with few on student housing infrastructure development. This confirms the initial expectation of the paper that there is scarcity of relevant information on risk factors in BOT student housing development. This, no doubt, indicates a need for further research in this direction. However, it is believed that the risk factors in other BOT project types can as well serve as pointers to what can be found as the risk factors in student housing development.

3.1 *Year of article publications*

The study aims to understand the trend of article publications over 1994 to 2024 regarding risks in BOT student housing infrastructure development. Researchers' interest in this topic increased gradually from 1994 to 2004, with a significant rise in publications from 2012 to 2017 and a peak of 267 articles in 2022 (Figure 2). The focus of research is shifting towards exploring risk factors influencing BOT success, as seen in recent studies by Osei-Kyei *et al.* (2022), and Fu *et. al.* (2023), although there is limited discussion on key issues affecting these risk factors in BOT student housing.

3.2 *Process of article selection*

Based on the 194 journal outlets discovered, keywords such as risk, risk factors, risk management, risk assessment, risk mitigation, PPP, BOT project types, CRFs, CSFs, etc. were inserted in the filter bar to generate bibliometric data on journal articles relevant to the research subject between 1994 and 2024. Thus, Table 1 indicates 12 journal outlets of the 614 articles from which 38 articles were retained. The criteria adopted are based on their number of citations and total link strength as related to the topic of discourse. These journal outlets have 614 articles from which 38 relevant articles are retained for this study.

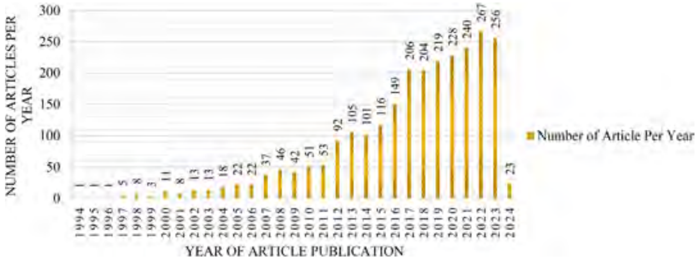

Figure 2. Trend of journal article publication on PPP/BOT risk assessment. Source: Authors' analysis of reviewed articles (2024).

3.3 *Articles' journal outlets*

Table 1 indicates that Engineering Construction & Architectural Management, Journal of Construction Engineering & Management, Sustainability, International Journal of Project Management, Construction Management & Economics, International Journal of Construction Management, and Journal of Infrastructure Systems have considerable link strength between 22,432 and 11, 099. This implies that the selected journal outlets are of high-impact factor even in terms of the overall number of citations.

Table 1. Analysis of journal outlets and numerical breakdown of relevant articles selected.

Journal Outlet	No. of Article	Article selected for the study	No. of Citation	Total Link Strength
Engineering Construction & Architectural Management	93	5	4,411	67.93
Journal of Construction Engineering & Management	86	5	7,568	116.55
Sustainability	70	4	362	5.57
International Journal of Project Management	50	3	10,883	167.59
Construction Management & Economics	49	3	5,485	84.48
SSRN Electronic Journal	49	2	88	1.36
International Journal of Construction Management	45	2	2,847	43.84
Built Environment Project & Asset Management	42	3	1,169	18.00
Journal of Cleaner Production	35	2	3,083	47.47
Buildings	33	4	448	6.90
Journal of Infrastructure Systems	31	3	1,672	25.75
Journal of Financial Management of Property & Construction	31	2	1,016	15.64
Total	**614**	**38**	**39,031**	**601.09**

Sources: Authors' analysis of reviewed articles (2024)

3.4 *Countries of articles' origin*

The outcome of the scientometric analysis in Table 2 indicates that China has the highest number of 151 articles with 165.51 total link strength, while Taiwan is the least with 9 published articles and 11.29 total link strength between the period of 1994 and 2024. This result is closely related to that of Fu *et al.* (2023); Osei-Kyei *et al.* (2022); and, Osei-Kyei and Chan (2015) except that Australia leads the US and the UK in this analysis. Also, prolific authors such as Chan A.P.C, Ke, Y., Zang, X., et cetera, published large number of their studies on PPP issues affecting China, and this aided vast articles that originated from the country. However, their studies hardly utilise student housing as case study among other BOT project types.

Table 2. Research articles per country.

Country	Article Per Country	Citation Frequency	Average Citation	Total Link Strength
China	151	10,638	30.66	165.51
Australia	104	8,656	36.37	124.10
United Kingdom (UK)	89	7,474	36.64	74.34
United States (US)	71	2,809	17.23	56.86
India	35	1,362	16.81	24.65
Italy	20	893	19.41	15.64

(*continued*)

Table 2. Continued

Country	Article Per Country	Citation Frequency	Average Citation	Total Link Strength
South Africa	17	500	12.50	14.74
Netherlands	17	1,521	39.00	13.39
Singapore	15	1,193	35.09	12.53
Malaysia	14	561	17.53	12.00
Canada	11	624	24.00	6.92
Ghana	11	474	18.96	13.19
Germany	10	582	24.25	6.43
Nigeria	10	206	8.58	11.99
Indonesia	10	50	2.17	8.77
Iran	10	449	20.41	14.58
Turkey	9	233	11.10	14.16
Taiwan	9	806	40.30	11.29
Total	**614**	**39,031**	**411.00**	**601.09**

Sources: Authors' analysis of reviewed articles (2024)

3.5 *Researchers' bibliographic mapping*

The link strength of the prominent authors shows the level of collaborative studies existing in the domain. To rank authors' contributions in collaborations, Howard *et al.* (1987) developed a quantitative method. With the method, the study assumed that the first author contributes more than the second, and the second author contributes more than the third. This method has been utilized in previous literature reviews such as Osei-Kyei and Chan (2015). The formula therefore given as:

$$\frac{1.5^{n\ 1}}{\sum_{i\ 1}^{n} 1.5^{n1}}.$$

Where:

n = number of authors
i = arrangement of each author in the order of contribution

By this formula, Osei-Kyei and Chan (2015) assigned one point to every article regardless of the number of authors. And, the one point was divided into equivalent parts for each author. Table 3 indicates the analysis of the score distribution for authors according to their order of appearance.

Table 3. Score matrix for multi-authored journal articles.

	Arrangement of authors				
Number of authors	1	2	3	4	5
1	1				
2	0.6	0.4			
3	0.47	0.32	0.21		
4	0.42	0.28	0.18	0.12	
5	0.38.	0.26	0.17	0.11	0.08

Sources: Howard *et al.* (1987) and, Osei-Kyei and Chan (2015)

Using the VOSviewer, the analysis in Table 4 indicates the selection of authors, their previous studies, and the overall collaborative strength attained in this research domain. Thus, the threshold used to filter over 4,876 authors and co-authors was based on at least 10 journal publications and 120 total citations.

Table 4. Analysis of journal authors, articles retained and the strength of collaboration.

Author	Article Retrieved	Relevant Article Retained	Number of Citation	Total Link Strength
Chan, APC	96	3	6,113	704
Osei-Kyei, R	37	2	2,351	376
Ke, Y	33	2	2,116	278
Zhang, X	33	3	2,116	217
Ameyaw, E.E.	22	2	1,411	195
Chen, C	22	1	1,411	183
Liu, Y	31	2	1,999	178
Wang, S	30	2	1,881	174
Jin, X	22	2	1,411	166
Liu, J	20	1	1,293	121
Wang, X	30	3	1,881	108
Martek, I	18	1	1,176	105
Yuan, J	18	1	1,176	102
Love, P.E.D.	31	3	1,999	98
Wang, Y	28	2	1,763	92
Smith, J	18	1	1,176	91
Chileshe, N	20	1	1,293	78
Wang, L	20	1	1,293	75
Pellegrino, R	18	2	1,176	68
Edwards, D.J.	26	1	1,646	66
Li, H	18	1	1,176	56
Kumaraswamy, M.M.	18	1	1,176	51
Total	**614**	**38**	**39,031**	**3,582**

After the filtration, 22 first authors met the requirement. Also, following the critical examination of journals by these researchers, 38 articles were considered out of the 614 articles shortlisted from the databases (see Table 4).

3.6 *Key terms analysis and discussion*

This section examines the results in Table 5, which indicates the number of times that each key term occurs in the 38 articles selected. Threshold for selecting key terms was based on at least 30 times of occurrence. The VOSviewer was used to analyse relevance of each key term, hence the relevance scores in the table.

Table 5. Key terms extracted from the extant literature.

Key Themes	Occurrences	Relevance Score
PPP	1498	0.4354
Risk	1333	0.8564
Risk factor	248	0.8719
Risk assessment	211	0.2440

(*continued*)

Table 5. Continued

Key Themes	Occurrences	Relevance Score
Risk management	183	0.6738
Public sector	149	0.1377
Infrastructure development	134	0.5823
Risk allocation	131	0.0970
Critical success factor (CSF)	128	2.7809
BOT	108	0.6086
Risk identification	98	0.1553
Public-private partnerships	92	0.6122
BOT project	81	0.5783
Private investor	80	0.1426
Assessment	74	0.6574
Project risk	66	0.6823
Success factor	64	1.9348
Critical factor	55	0.5772
Value for Money (VfM)	50	0.4526
Private finance initiative	31	0.1474

Sources: Authors' analysis of reviewed articles (2024)

3.7 *PPP/BOT: A private finance initiative option for public infrastructure procurement*

Public-private partnership (PPP) alongside its variant, build-operate-transfer (BOT) are frequent research themes in the articles reviewed. The analysis (Table 5) also indicated the strength of risk and PPP over other themes in the past researches. Again, the top public projects procured through PPP/BOT include toll road construction, airports, power projects, water projects, toll roads, public housing, and health facilities while educational facilities were not frequent among the PPP/BOT project types in the previous articles. The result reveals the classes of 345 PPP/BOT projects identified from the selected articles, of which only 3 case studies are for PPP/BOT educational facilities. There are few such projects probably owing to the investors' keen interest in economic goods rather than social goods. Thus, researchers might hardly consider educational facilities as their case studies since they are uncommon PPP/BOT project types within the usual study areas. However, it is a great concern because most Nations' economic developments leverage both educational and technological advancements (Oyeyoade and Araloyin 2019). There is a need to galvanise research towards all-inclusive risk factor mitigation to harness PPP models for student housing infrastructure development.

3.8 *Risks and risk factors in BOT*

Risk is the most compelling theme in BOT infrastructure development. This is evident by the analysis of the reviewed articles (Table 5) where risk as a theme has an occurrence rate of 1,333 and relevance score of 0.8564. As remarked by Ayodele and Olaleye (2018), risk is inevitable in any investment. According to Ghadage *et al.* (2020), risk is understood by individuals in different ways depending on discrete viewpoints, attitudes, and experiences. In the analysis of this study, most research articles dwelt on risk issues affecting various types of PPP/BOT projects. Among these articles are Ameyaw and Chan (2015) which focused on risk allocation in the Ghana water project; Babatunde and Perera (2017) examined revenue risks in BOT road projects in developing countries; Carbonara *et al.* (2015) investigated risk management in motorway PPP projects. Again, these articles developed thematic groups for risk factors. However, no specific article with strong link strength considers risks in educational facilities procured through the PPP/BOT model other than the generalised risk scenarios.

3.9 *Risk assessment*

Assessment of risks entails the detection of potential risks, accurate analysis and evaluation to ensure proper risk identification and classification that will aid the allocation of risks to the PPP/BOT stakeholders. Table 5 indicated that risk assessment has a total occurrence rate of 211. Several authors like Carbonara *et al.* (2015); Wu *et al.* (2018) stated that the assessment of individual risk depends on their probability of occurrence and the level of severity. Babatunde *et al.* (2018) added that circumstances surrounding risk are also important when executing risk assessment. To standardise the risk assessment process, previous researches either utilised qualitative or quantitative approaches. However, some researchers that combined both approaches often start with qualitative methods using descriptive techniques to express the likelihood and the possible impact of individual risk. Thus, the viewpoints and the experience gathered through the qualitative approach alongside the relevant data are employed to determine the likelihood and the severity level of potential risks (Ghadage *et al.* 2020). However, the results of the quantitative approach are more accurate than the qualitative assessment. It was added that the results of the qualitative assessment are to guide the assessor on the execution of quantitative assessment (Osei-Kyei *et. al*. 2022). But some observed that these approaches have been deployed to assess risk factors in various classes of PPP/BOT projects, but it is not clear if any researcher considers such for educational facilities procured through the variants of PPP.

3.10 *Risk identification, classification and allocation*

Risk identification is the first step in the risk-mitigating process. It involves recognising and analysing the risks that could affect the project's objectives. The importance of risk identification as a key term occurred 98 times in the numerical analysis of the past studies (see Table 5). Ghadage *et al.* (2020) argued that risk identification is a constant process to risk mitigation for the sustenance of BOT concession through its lifecycle. Therefore, to maintain the constancy various methods have been suggested by the researchers. For instance, Li *et al.* (2005) and others suggested risk checklist, risk workshops, Delphi technique, etc., while Tang., Shen and Cheng (2010) and others developed risk register as the database for risk monitoring and adaptation. However, risk identification might not be effective for risk control and management without accurate risk classification to initiate risk sharing among the stakeholders.

Risk classification can be described as grouping potential risks based on their likelihood (occurrence), circumstances and severity at a period. Extant studies have showcased the same major categorisation of risks in PPP/BOT with imbalanced information on the underlying risk factors. Despite its role of providing the link between risk identification and risk allocation when mitigating risks in BOT, risk classification was missing among the key terms, and it has no attributed value regarding the rate of occurrence and relevance score in the numerical analysis of the reviewed articles.

In most articles reviewed risk allocation was called risk sharing. Studies suggested that the allocation of BOT risks must occur at the preliminary stage of the concession and must be reflected in the memorandum of understanding (MoU) signed by the stakeholders to avoid contractual disputes that may affect or terminate the project. Interpreting the numerical analysis of the selected articles revealed that risk allocation has a total frequency of 131 (see Table 5). This suggested how crucial is this term in PPP/BOT risk research. Based on its importance, some studies reviewed concluded that risks should be allocated to the stakeholders with the capacity and expertise to control or manage risk scenarios through effective mitigation plans and techniques. Though Li *et al.* (2005); Ke *et al.* (2010) opined that transferring all risks to private investors may undermine project performance. However, recent studies on risk mitigation in BOT projects have discovered that existing risk allocation methods do not provide an optimised problem-solving process. Thus, the stakeholder relationships become threatened.

3.11 *Critical Risk Factors (CRFs) versus Critical Success Factors (CSFs)*

CSFs are the key areas or elements crucial for the successful execution and delivery of the project objectives (Babatunde and Perera 2017). These factors are typically related to project management, stakeholder engagement, resource allocation, technology implementation, risk management, and performance measurement. CSFs are the essential drivers of project success, and their effective management can lead to achieving the intended project goals and outcomes.

Various studies have come up with CRFs and CSFs classifications in line with the BOT stages such as feasibility, procurement, construction, operation and transfer stages. Also, studies such as Al-Azemi, Bhamra, and Salma (2014) categorized CRSs into endogenous and exogenous risks based on how they occur. The endogenous risks occur from within the BOT environment and could be controlled by the stakeholders. The exogenous CRFs are externally originated. The stakeholders cannot manipulate them and thus need expert input to mitigate. Through these classifications, framework to contain new risks have been developed.

3.12 *Mitigation of CRFs and improvement of CSFs*

Ke *et al.* (2010) opined that risk mitigation is a measure adopted to reduce the effect of risk in PPP concessions. Despite this relevance, few studies focused on risk mitigation over the three decades under review. The numerical analysis of the key terms deduced from the selected articles shows no occurrence rate and relevance score for risk mitigation. However, it will be an oversight for the researchers of BOT risk factors to downplay risk mitigation, hence the necessity to discuss its utilisation for CRFs palliation.

To mitigate CRFs, some studies utilised theories and techniques, including fuzzy set theory (Ameyaw and Chan 2015), bargaining game theory (Li *et al.* 2017), and Monte Carlo simulation (Carbonara *et al.* 2015) among others. Also, few studies on risk mitigation strategies suggested measures like high contingency budget for financial risk; stakeholders familiarisation to mitigate legal, regulatory and political risks; adequate consultations at the preliminary stage to avoid some construction risks and proper conduct of environmental impact assessment (Tang *et. al.* 2010). Following these, research interest in risk mitigation should encompass the peculiarities of social goods like student housing development.

4 CONCLUSION

Various researchers have offered diverse perspectives on addressing the influence of risks in Build-Operate-Transfer (BOT) projects. Yet, private investors and education institutions in student housing development have not fully benefited due to generalised opinions. To bridge this research gap, this study conducted a systematic review utilising scientometric analysis on articles published between 1994 and 2024 as extracted from Scopus and Dimension AI databases.

The study reveals and confirms a consistent increase in research on risk factors in PPP/BOT for other project types since 2007, but with few or insufficient attentions on student housing infrastructure development. Countries such as China, Australia, the UK, and the US are leading in article contributions, while a bibliographic analysis identified 22 persistent authors in this field. Key terms like PPP, risk assessment, infrastructure development, and BOT projects were prominent but neither student housing nor educational infrastructure were given attention, unlike other BOT project types. The study thus concluded on the need to encourage more research on risk factors in BOT student housing development.

Further research on risk classification and mitigation strategies for BOT projects with social attributes, such as student housing, aiming at supporting practitioners, policymakers, private sectors, and procurement authorities in successfully delivering student housing infrastructure development is recommended. While this paper found limited articles related to student housing infrastructure development and indicates a need for further research in this direction, the risk factors in other BOT project types can serve as pointers to what can be found as the risk factors in student housing project.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

Salient factors that contribute to unsuccessful competitive bidding by small construction contractors from contractor experience viewpoint, case of Malawi

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ABSTRACT: Successful competitive bidding is the ultimate goal of construction contractors of all sizes. Researchers focused on factors affecting successful completion of secured projects. Nevertheless, a critical subject that was given a little attention by researchers is the factors hindering successful competitive bidding. This paper focusses on identifying the factors contributing to unsuccessful competitive bidding from viewpoints of 204 contractors experience. The sample size was obtained through stratified sampling to respond to the questionnaire survey. The results showed 8 salient factors by mean index analysis and Spearman correlation coefficient. These factors include contractor past experience; ineffective tender advert; crosscategory competition, lack of guarantee; corruption; low annual turnover; lack of plant as well as bank policies on loans. This study has implications on industry practitioners, researchers and academia as it provides salient factors to consider for the successful competitive bidding. It also provides a basis and reference for further and comparative research.

Keywords: Competitive bidding, small contractors, construction, tendering, building

1 INTRODUCTION

The construction industry in Malawi is well organized and established in a way that the industry players contribute considerably to its development and that of the country at large (ACF 2019), (Kadangwe and Emuze 2017). However, like in other countries, small construction contractors in Malawi face tremendous challenges in securing projects through competitive bidding (Nsabimana *et al.* 2022). Notably, small construction contractors rely on public sector to secure projects that fall under their financial capacity and some small projects from the private sector, generally comprising of maintenance and refurbishment projects (Kadangwe and Emuze 2017).

The competitive bidding process provides project information to all bidders equally. In this method of project delivery, Tenders are highly competitive, and proposals, are usually evaluated against a set of controlled criteria in order to determine which tender represents the economic advantage to the client (Alsulamy 2022). From this background, the academic literature has been focusing on the factors influencing the underperformance of contractors on successfully secured projects. While there are number of factors that may contribute to the failure of contractors to secure projects through competitive bidding, this matter has not received the due attention it deserves in Malawi. This paper aims at identifying the factors that contribute to unsuccessful competitive bidding by small construction contractors following contractor experience point of view, in Malawi.

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1.1 *Small construction contractors in Malawi and successful bidding overview situation*

Small construction contractors in Malawi are the ones that can compete for projects valuing up to 50million Malawi Kwacha with staff not greater than 20 employees. The national construction industry council (NCIC) registry 2021 indicated this class to be 55.2% of total registered building contractors and 69.8% of total registered civil contractors (Nsabimana *et al.* 2022). These values demonstrates the importance of improving the performance of small construction contractors especially in competitive bidding to promote the construction industry in Malawi.

The failure to secure projects for small contractors limit their chances to grow and they do not positively contribute to the development of the country. The current research published by Nsabimana *et al.* (2022) shows the rate at which small contractors in Malawi have been securing project, where 69.1 percent of the study sample secured between 0 to 6 projects in the span of 5 years. In this rate, 9.3 percent is for small contractors that did not manage to secure any project between 2017 and 2021. Moreover, Kulemeka, *et al.* (2015) exposed 8,238 cases of bids rejected between 2007 and 2011 due to different factors including lack of financial and non-financial resources as well as lack of experience in bidding.This indicates why it is imperative to find out the emerging reasons that contributed to the low success of small contractors in competitive bidding.

1.2 *Factors that influence the successful bidding for infrastructure projects from the literature*

The factors that influence this kind of low performance in successfully securing projects for small construction contractors cannot be exhausted. This research grouped the variables obtained in the literature in categories to deeply examine them (Cattani 2017). Among them, there are factors related to company attributes which refer to the contractor's internal strategies and trends that capacitates its ability to participate in the competition (Obodo *et al.* 2021). The extensive assessment of the client's needs and competitor's attributes improve the contractor's self-confidence in the most aggressive competition (Setiawan *et al.* 2015. Small-scale contractors are subjected to shortage of capital and funding for working and growth (Gundes *et al.* 2019). At the absence of advance payment, contractors run to the Banks and insurance firms to get loans and guarantees. Nevertheless, commercial banks consider small construction contractors to be high-risk clients, and tend to limit their loan amount and increase the interest rate (Zidana 2015). The alternative mechanisms established by governments to increase the business financing for small and medium businesses may also be slow to boost the financial situation of small construction contractors (Olanipekun 2020). Small contractors need to be equipped with soft resources like technical, managerial and entrepreneurship skills to prove their good standing in competitive environment (Aghimien *et al.* 2019). This is provided through training and mentorship programmes established by partners and industry stakeholders (Garavan and McGuire 2014). Moreover, lack of physical resources including personnel, plants and equipment may be the reason of refusal or cancelation of bidding applications. The failure of small contractors to secure projects can be linked to the insufficient industry support by the state in providing a level field for competition. The political willingness to reduced corrupt practices and unfair competition is demonstrated in updated policies for both public and private sector set by the state (Nordin *et al.* 2011). The state also establishes functioning institutions committed to support small-scale contractors throughout the value chain as a contribution to ensure their growth (Chingaipe and Leftwhich 2007). This paper aims at identifing the salient factors that contribute to unsuccessful competitive bidding by small construction contractors in Malawi, from contractor experience point of view. This quantitative research used a questionnaire designed from variables identified through comprehensive literature review, and tested on small construction contractors in Malawi. The research contributes to the body of knowledge and inform industry practitioners and stakeholders as well as academic and professional researchers who are interested to further their study on this affair.

2 MATERIALS AND METHODS

2.1 *Sample size and selection*

This study was undertaken in Malawi in 2022. The study area is one of the least developed countries in the Southern African Development Community in the southern hemisphere with the highest number of small-scale contractors with many cases of contractor's failure in competitive bidding. The foregoing characteristics presented themselves as a candidate for the study. The study was conducted following quantitative approach. This approach was chosen because the research variables were collected from recent publications through comprehensive literature review, and the data collected was quantitative in nature.

The research variables and their categories that were gathered through comprehensive literature review were further used to design the questionnaire. A set of 56 factors were recorded and categorized in 6 categories. Table 1 shows the factors identified through comprehensive literature review and their categories.

Table 1. Factors identified through comprehensive literature review and their categories.

Category of factors	Factors identified	References
Factors related to company attributes	Lack of experience on bidding	Ali *et al.* (2020) and Orozco *et al.* (2014)
	Lack of marketing strategies	Matysek-Jedrych (2012) and Sekerin *et al.* (2015)
	Lack of competitiveness strategies	Komarkova *et al.* (2014) and Lisowska (2013)
	Negative contractor's Perception	Bee-Lan OO *et al.* (2021) and Megh B. K. C *et al.* (2020)
	Lack of capital	Bondinuba F. K. (2012) and Yashino N and Taghzadieh-Hesary F. (2016)
	Past experience on execution of jobs	Kent D. C. and Becerik-Gerber B. (2010)
	Lack of biding skills	Harijanto *et al.* (2015) and Yan (2015)
	Misunderstanding of tender terms	Johari *et al.* (2019) and Karua (2012)
	Failure to get work regularly	El-Mashaleh M.S. (2013) and Lee *et al.* (2014)
	Bid price above/below owner's estimated price	PJ Kulemeka et al. (2015)
Factors related to finance	Inability to get loans	Hesham A *et al.* (2018) and Shash A. A., and Qarra A. A. (2018)
	Lack of collateral	Banda K. (2020) and Kulemeka P. J. *et al.* (2015)
	High interest rates by banks	Branchard O. (2019) and Dimitri V. and Jean-Luc V. (2021)
	Poor bank policy towards SMEs	Ndala N. N. (2020) and Wonglimpiyarat J. (2015)
	Lack of bid security	Vladmirov V. (2015) and Obodo *et al.* (2021)
	Low annual turnover	Oo B.L. and Tang O. S. (2023) and Petronijević M. *et al.* (2015)
State related factors	Insufficient focused industry support	Sharma K.V. and Singla R.K. (2015)
	Inequitable contracting prac-	Ali I.F. *et al.* (2021) and Zhu L. and Cheung

(*continued*)

Table 1. Continued

Category of factors	Factors identified	References
	tices in public institutions	SO. (2022)
	Lack of policies to develop indigenous contractors	Foley D. and Hunter B. (2013) and Balouga J. (2012)
	Unfair competition with foreign/local contractors	Osabutey ELC *et al.* (2014) and ACF (2019)
	Corruption	Clarke G.R.G. (2010) and Kadim N. *et al.* (2021)
	Lack of institutions to support small contractors	Ofori G. (2015) and Ness K. (2012)
	Political interference	Beke M.B. (2018) and Chingaipe H. and Leftwich A. (2007)
Industry related factors	Low profit margins	Bork RH and Sidak JG (2013) and Carter M. (2019)
	Long registration process	ACF (2019)
	Registration and high annual membership fees	ACF (2019)
	Lack of construction associations	ACF (2019)
	Cross category competition	Kulemeka P.J. *et al.* (2015) and Afionis S. (2020)
	Concentration levels in different class,	ACF, (2019)
Factors related to non-financial resources	Shortage of staff	Ali *et al.* (2020)
	Lack of professional advisors	AO Windapo (2016)
	Lack of training	Olatunji S. (2020)
	Lack of technical skills	Kamanga MJ, Steyn WJ V d M (2013) and PHK Ho (2016)
	Lack of entrepreneurial skills	Alsulamy S. (2022)
	Lack of management skills,	PHK Ho (2016)
	Lack of mentorship	MW Nkomo and WD Thwala. (2014)
	Lack of financial skills	IFC (2020) and Deleen and abonsu (2002)
	Low strength of human resource	Opeyemi *et al.* (2016)
	Lack of plant	Deleen and abonsu (2002)
	Lack of equipment	SB Bista and RK Dahal (2018)
	Lack of IT experience	Paudyal G. and Prakriti K. (2016) and Cherian TM and Kumaran LA (2016)
Client related factors	Focus on lowest bids	Khan T.H. and Khan A.Q. (2015)
	Over complex contract conditions	Obodo *et al.* (2021)
	Marginalizing local companies	Jaman and Margaret (2013)
	Preference given to foreign firms,	Elijah *et al.* (2020)
	Ineffective advertisement of tender,	Jin (2018) and Mathon-si MD and Thwala WD (2012)
	Decline in the number of capital projects	Ntuli and Allopi (2014)

For a company to participate in the survey, they had to be registered in the 4 classes indicating small contractors and willing to contribute to the survey by providing the correct information.

The small contractors registered, as civil contractors were 513 while those registered, as building contractors were 321 and 229 registered as both civil and building contractors. The total population was 1,063. To calculate the sample size, the confidence level of 95 and 0.05 as precision were considered. The sample size was computed using Yamane's formula as follow:

$ɲ = \upsilon(1+\upsilon e^2)$-1, where ɲ=sample size; v=population; e=margin.

The sample size computed was 283.

This size was then dispatched through stratified random sampling technique to compute the sample size in each category by using Cochran's formula as follow:

$$S = \frac{Size\ of\ the\ stratum \times Sample\ size}{size\ of\ population}$$

Thus, the sample size was distributed as 127 contractors in civil, 116 in building and 40 contractors registered in both building and civil categories. Contractors were then selected following random sampling techniques after stratification. The sample was then characterized by four attributes, namely: company category; company size; annual turnover and company experience.

2.2 *Data collection*

Questionnaire survey was used to collect data from respondents. The questionnaire was adopted based on the quantitative data to be collected and a set of questions with multiple choice answers. the respondents simply had to tick the most accurate choice based on his understanding to the question asked. Furthermore, questionnaire is suitable for its ability to reach the targeted audience scattered countrywide, its ease of providing necessary information in research and the ability to analyze and generalize the feedback (Kothari 2013). The respondents had to rate the factors in the questionnaire following a 5 points Lickert scale representing strongly disagree (0), disagree (1), moderate (2), agree (3) and strongly agree (4). Respondents had to choose and tick the appropriate attributes among others in the questionnaire.

The questionnaire was pre-tested to 15 experts from academic and industrial sectors. The purpose of pre-testing was to ensure the clarity, adequacy of questions and the time it takes to respond to the questionnaire (Cooper and Schindler 2014). Minor changes were adjusted after the feedback from experts confirming the use of the questionnaire.

After pre-testing, the questionnaire was sent to small construction contractors to elicit data. It was sent by email with option of answering through Google form or completing the attached word form questionnaire and return it back. This was done to allow the respondents answer flexibly and increase the rate of responses. The 204 valid responses were received representing 72.1 percent of the sample size. Easterby-Smith (1991) Pointed out that the expected response rate from industry is of the order of 25–30%. The aforementioned response rate led to a corresponding confidence level of 95 per cent.

2.3 *Data analysis*

Statistical Package for Social Science, SPSS 21.0 was used for data analysis. The analyzed. The company attributes were analyzed by frequencies and percentage while factors of research were analyzed by mean indices and ranking to determine the ratings by category and spearman correlation coefficient to determine the strength of correlation between factors and contractor's experience.

3 RESULTS

3.1 *Sample attributes*

The company's attributes were analyzed by descriptive statistics and are shown in Table 2. Results show that in 204 participants, 38.7% were registered in building category, while 36.3% were from civil category and 25% were in both civil and building categories. This gives an overview that all categories of contractors in the construction industry were represented.

Moreover, 21.1% of small contractors had less than 2 employees, 46.1% had 2-5 employees while 32.8% had more than 5 employees. The analysis of financial capacity of contractors showed that 22.5% could compete for projects less than 20 million Malawi Kwacha. 35.3% were for 20 million Malawi kwacha while 42.2% were above 20 million Malawi Kwacha. For experience, most of respondents were still at beginning stage as 34.3% were in the range of 1 to 3 years' experience while 40.2% were in the range between 3 to 6 years.

Table 2. Respondent characteristics.

Sample characteristics	Frequency	Percent
Company category		
Building	79	38.7
Civil	74	36.3
Building & Civil	51	25.0
Company size		
<2 people	43	21.1
2-5 people	94	46.1
>5 people	67	32.8
Company annual financial turnover		
<K20 m	46	22.5
K20m	72	35.3
>K20 m	86	42.2
Company experience		
1-3 years	70	34.3
4-6years	82	40.2
7-10years	30	14.7
>10years	19	9.3

3.2 *Mean indices and ranking of factors with respect to contractor's experience*

The importance of each factor was described in the form of interval scale. The factors having mean index of $2.50 \leq \mu < 3.50$ and $3.50 \leq \mu \leq 4.00$ are considered as "agree" and "strongly agree" and are considered to have a significant contribution to unsuccessful bidding for infrastructure projects . While mean indices of $1.50 \leq \mu < 2.50$; $0.50 \leq \mu \leq 1.50$ and $0.00 \leq \mu < 0.50$ represent "moderate", "disagree" and "strongly disagree" responses, meaning to have little to no contribution to unsuccessful bidding for infrastructure projects. 8 factors out of 56 were identified to have a significant impact with contractor experience perspective. The most ranked was past Contractor experience ($\mu = 3.29$) which falls under company related factors followed by Ineffective tender advert ($\mu = 3.00$) which falls under client related factors. Cross category competition ($\mu = 2.97$) was next and is found in industry related factors and Lack of guarantee found in financial related factors ($\mu = 2.89$). Following was Corruption ($\mu = 2.88$) which is in state related factors; Low annual turnover (μ= 2.76) found in financial related factors; Lack of plant ($\mu = 2.60$) which is in factors related to physical resources as well as Bank policies on loans ($\mu = 2.55$) which falls under financial related factors. Table 3 presents the results of mean indices, ranking and correlation analysis.

3.3 *Correlation analysis*

A Spearman's correlation was analyzed to determine the relationship between the contractors experience and the factors. There was a strong, positive and monotonic correlation between contractor's experience in industry and contractor's experience in project delivery (R = 0.76); cross category competion (R = 0.98); corruption (R = 0.96) and lack of plant (R = 0.92). However, a strong negative correlation was observed between contractor's experience in industry and low annual turnover (R = – 0.76).

Table 3. Mean indices, ranking and correlation.

Factor	Category	$\mu 1$	$\mu 2$	$\mu 3$	$\mu 4$	μ Mean	Spearman R	Rank
Contractor's past experience	Company	2.86	3.20	3.32	3.75	3.29	0.76	1
Ineffective tender advert	Client	3.41	3.09	2.73	2.77	3.00	−0.11	2
Cross category competition	Industry	3.30	3.07	2.93	2.59	2.97	0.98	3
Lack of guarantee	Financial	2.87	3.11	2.80	2.77	2.89	0.47	4
Corruption	State	3.21	3.20	2.53	2.59	2.88	0.96	5
Low annual turnover	Financial	2.80	2.83	2.70	2.36	2.67	−0.76	6
Lack of plant	Resource	2.47	2.73	2.55	2.64	2.60	0.92	7
Bank policies on loans	Financial	2.66	1.96	2.70	2.86	2.55	−0.17	8

$\mu 1$: Mean indices from Companies having between 1-3 years' experience; $\mu 2$: Mean indices from Companies having between 4-6 years' experience; $\mu 3$: Mean indices from Companies having between 7-10 years' experience, $\mu 4$: Mean indices from Companies having more than 10 years 'experience

4 DISCUSSION

Small contractors agreed first that contractor's experience in delivering projects could hinder their successful competitive bidding. A contractor who successfully completed and handed over many projects has experienced several raises and falls throughout his journey compared to small contractors who completed few to no project (Azeem *et al.* 2020). Clients also consider experience as primary requirement during contractor selection (Chen and Ye 2021). If a contractor does not meet the required number of completed projects, then his bid will be disqualified. (Setiawan *et al.* 2015) Argued that competitive aggressiveness of a contractor is built over time as the contractor learns from his mistakes. However, small contractors at beginning stage can win competition if they learn from others and if they are well equipped with employees experienced in the industry in a particular location.

Ineffective tender advert received a second rank in agreement. This occurs when contractors prefer one mode of advertising than others. (Nyasulu and Chawinga 2018) found that most of health projects became successful by considering owners in Malawi prefer written newspapers than other sources for tender advertisement. This may limit small contractors to get information about projects if they use other sources of information. However, (Groda 2017) argued that for the tender advert to be successful, clients and contractors, no matter their size should consider publishing in varied sources of information. There are other emerging sources of information including printed, electronic and social media, which can also serve better in this digital era.

Crosscategory competition refers to how contractors are limited in their classes. Normally, the lower class cannot compete for larger project. However, in some cases and locations, categories higher classes can compete for smaller projects that could be competed by lower classes (ACF 2019). In addition to the lack of equilibrium for small contractors, cross category competition has a considerable impact on pricing the construction projects (Karray *et al.* 2020). If the barriers between classes are not properly set and enforced, small contractors are at high risks of lack of jobs and withdrawn from the industry.

Lack of guarantee is another thorn on small contractors' competition. First, and most obviously, small contractors need customers and access to credit (Egwunatum and Awo-Osagie 2018). This is much harder for small construction contractors to obtain than large construction contractors with assets. According to Jin (2018), small contractors grow by acquiring both customers and knowledge of their market. If they have to shed employees, they lose "business knowledge and experience", which sets them back even further in their recovery. It implies that access to finance initiatives should be enhanced especially for small contractors.

Corruption is a risk for businesses of all shapes and sizes, but those operating within construction industry may be particularly vulnerable (Bamusi 2023) . It affects the competition as it influences the outcome of the bidding process (Clarke 2010). The construction industry consistently ranks high in corruption indexes, and Malawi organizations are not immune (Chan and Owusu 2017) argued that bureaucracy involved in construction can also expose organizations to vulnerability, as projects usually require numerous licenses and permits, with each one providing an opportunity for bribery. Sub-contracting may also contribute to the issue, as the complex chains of transactions between different organizations can make control measures difficult to implement and increase the opportunities for bribery (Chiang 2009). It is therefore necessary for procuring, industry regulation bodies, and other related institution to monitor and follow up the implementation of legal, inspection and ethical measures taken by countries to combat corruption (Karimi 2020). So, the gaps existing in administrative entities including bureaucracy, lack of transparency and political interference in government related projects should be bridged by the use of technology. In this context, registered contractors can tender public projects and from international non-government organizations through a well-monitored system (Mutangili 2019).

5 CONCLUSION

This paper evaluated 56 factors contributing to unsuccessful competitive bidding of small construction contractors, from contractor's experience viewpoints. Following a quantitative approach, questionnaire survey was used on small contractors registered with the National Construction Industry Council of Malawi. Data analysis was done by mean indices on 5-point Lickert scale and ranking, while correlation was run with Spearman's correlation coefficient. The mean index analysis indicated that small contractors agreed on eight factors among others contribute to unsuccessful competitive bidding. The first four downward are contractor past experience of completed projects; ineffective tender advert; cross category competition and lack of guarantee. The other four descending are corruption; low annual turnover; lack of plant as well as bank policies on loans. The findings revealed in this study have implications on industry stakeholders, researchers and academia that the above-mentioned factors influence the unsuccessful bidding mainly for small construction contractors. This can be amended through policy review to consider supporting small construction contractors. Regulations that are practical to the problems identified in this research as well as paradigm shift on the side of clients and banks regarding small construction contractors can affect positively the results on successful competitive bidding. This research gives insights of considering small construction contractors as a unique class to focus on their growth. It also provides a basis and reference for further and comparative research.

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Development and Investment in Infrastructure in Developing Countries – Musonda et al (Eds)

The adjudication and demarcation of land parcels in cross border areas - A case of Malawi – Tanzania border at Songwe-Nkhanga

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ABSTRACT: Land is the ultimate resource and fundamental to people in the developing world, but in recent times, its access is becoming more tenuous than ever as the population is growing rapidly. Both Malawi and Tanzania are countries that are experiencing rapid urbanization, with pressure on land and infrastructure in urban and peri-urban areas including border areas due to increase in cross-border activities. The land parcels in the cross-border areas are rendering it difficult to be properly adjudicated. There is no guiding processes and legal framework on how such land should be registered to ensure tenure security. Secure land tenure provides a foundation for planning and implementing projects that require land acquisition for infrastructure development. A concurrent mixed research was adopted and the sample was purposively selected. The study reveals that the law is silent on how land that borders two countries should be treated for the purpose of registration.

Keywords: Land tenure, Land Adjudication, Land Demarcation, Border areas, Boundaries

1 INTRODUCTION

Land is an economic resource and an important factor in the formation of individual and collective identity, and in the day-to-day organization of social, cultural and religious life (Gbenga John *et al.* 2017). Most people in Africa are deemed to be wealthy when they have land rights ascertained to them(Smucker 2002).Gbenga John *et al.* (2017) further states that land accessibility are the processes by which people (individually or collectively) gain rights and opportunities to occupy and utilize land primarily for productive purposes and other economic and social purposes, whether on a temporary or permanent basis. Land ownership and accessibility is the catalyst for economic development from individual to national level. The majority of Africans rely on customary land on which rights to cultivate and transfer land is guided by traditional chiefs and Customary law governs its administration (Chinsinga 2008).A number of studies shows that there is considerable ignorance of both the law and procedures related to land ownership and development and dispute resolution in both rural and urban areas (Kironde 2009).Issues relating to land tenure and land reform have been the subject of numerous studies in recent years and there has been much debate on what sort of tenure regime is best suited for Sub-Saharan African conditions. It is commonly believed that land registration has a positive impact on agricultural and infrastructure investment and that indigenous systems of land tenure are a constraint on agricultural and infrastructure development and have come under serious challenge.(Abdulai and Ochieng 2017; Sundet 2004).

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Border settlements according to Oladehinde *et al.* (2018) are the settlements closer to the international border line between two countries including those that live along the boundary lines. Border settlements are characterized with vast land which can be used for farming, housing and infrastructure development, rural market, work area among others(Gbenga John *et al.* 2017). Border settlements have not been spared from tenure security issues, the nature of locality of border lands poses a complex approach in terms of land use and land ownership.

1.1 *Land reforms projects in Malawi and Tanzania*

The Government of Tanzania is implementing land tenure improvement project through the Ministry for Lands, Housing and Human Settlements Development (MLHHSD). The Project (LTIP) aims to strengthen the land administration systems and increase tenure security to men and women, and thus promote land-based investment in the Country. The project has several components that includes, increased tenure security, Land Information management,institutional strengthening and project management (Lands *et al.* 2020). This component supports the issuance of Certificates of Customary Rights of Occupancy (CCRO), Certificates of Rights of Occupancy (CRO), Residential Licences (RL) and other related activities.

Following the passage of the Customary Land Act of 2016, the Government of Malawi (GoM) piloted customary land documentation procedures across different areas of the country, including through the EU-supported pilot on: “Technical cooperation to strengthen national capacity in implementing land policies and laws efficiently and effectively” as well as through the World Bank-funded Shire Valley Transformation Project, and the Agricultural Commercialization Project. These pilots were facilitated through the Land Reform Implementation Unit(Brooks 2023).

In respect to the Land reform projects happening in Tanzania and Malawi respectively, during Land parcels adjudication and demarcation exercise currently underway, the parcels in the cross-border areas are rendering it difficult to be properly adjudicated and demarcated as land is subjected into two different land tenure systems , therefore there is a challenge of which system should the parcel be registered to and there is no guiding processes and legal framework on how such land should be registered to ensure tenure security for the cross border parcel holders and only limited research has been presented specifically on the policy making process itself and no study has been done concerning registration and adjudication of border lands between Malawi and Tanzania, It is against this background that this study has developed a framework on how parcels falling in two different countries should be demarcated without escalating land conflicts in the areas shared by two sovereign states.

2 OVERVIEW OF LAND PARCEL ADJUDICATION, DEMARCATION AND REGISTRATION

The adjudication and demarcation of land parcels in cross-border areas present a complex and challenging undertaking, requiring a great understanding of legal, cultural, and geographical factors. Adjudication is a prerequisite for intentions to register land rights, in itself land adjudication does not create rights, it only establishes existing rights, the identification of interests in land precedes the boundary mapping. The role of the boundaries therefore would be to confirm the limits within which those interests (already identified) in land apply (Anim-Odame 2021). Njeru, (1981) found out that land adjudication is expected to benefit rural landowners, in the sense that it would raise agricultural production and promote access to developmental facilities such as loans.

It is also expected to promote personal effort necessary for developmental purposes, this personal effort has been achieved, although the sociological disadvantages seem to override the economic advantages such as fragmentation. The purpose of land adjudication and demarcation is to register land in which land registration is a process of official recording of rights in land through deeds or as title on properties. It means that there is an official record (land register) of rights on land or of deeds concerning changes in the legal situation of defined units of land (Henssen 1995). According to Byamugisha (2016) land registration in Africa is still at low levels and cannot sustain transformation of Africa's agriculture, infrastructure and development. While Western European countries have on average more than 95 percent of their land registered, in Africa only about 10 percent of the rural land is formally recorded in a public register, leaving 90 percent held under customary law. Adjudication and demarcation are carried out hand in hand as interdependent activities in land registration processes whereby land demarcation is one of the earliest activities of organized human groups (Libecap and Lueck 2011) and it defines property boundaries, parcel shapes, and plot locations and, hence, is a foundation for land use and land markets (Arruñada *et al.* 2018).Demarcation is the measurement and delineation of boundaries by one or more of the parties that have an interest in the land (including Government agencies). Correspondingly, these initiatives often pay little, if any, attention to the legal dimension of land demarcation: the fact that, in order for demarcation to produce effects on third parties, such party-led physical demarcation must be accepted by all other interested parties, which in this case mainly means the neighbors of each particular parcel. This is done to clearly identify and distinguish one parcel of land from another. The demarcation of land is essential for various reasons, including legal, administrative, and practical considerations(Arruñada *et al.* 2018).

3 RESEARCH METHODOLOGY, ANALYSIS AND DISCUSSION OF FINDINGS

The research study used a combination of desk research and field research to investigate the best practices of the demarcation and adjudication of land parcel boundaries in border areas for the purposes of land ownership. The desk research involved a comprehensive review of the literature on existing practices on adjudication and boundary demarcation, as well as the legal and regulatory frameworks governing boundary demarcation and adjudication of land parcels in general as well as border areas. The research reviewed the land registration acts in both countries that govern the registration of land for customary, public, private, village and reserved land. The research study was done mainly on two fronts, firstly a comprehensive desk study was used to make inquiries and observation of selected secondary data; and secondly, hands on field data collection was done in the selected study areas in order to obtain primary data using Malawi Customary Land Mapping Tool (MCLMT). The data collection tool (MCLMT) has the capability to collect both attribute and spatial data at the same time using modified tables and inbuilt mobile global positioning system (GPS). The sampling technique that was used in this research study was purposive in nature. It involved mainly the customary/village land holders within the international boundary and parcels that have been directly affected by the international boundary line. The sample size was driven by the stretch of the boundary, for this study a stretch of 9.6 km with a buffer of 300 meters was chosen. Malawi and Tanzania Border has a total border of 474.756 km from which 464.756 is watershed and only 9.6 km is dry land representing 2.02% of the total boundary distance. For the purpose of this research only dry land was chosen. A buffer of 300 meters was chosen to allow depiction of greater parcel detail at a distance from the actual and perceived boundary.

Figure 1. Boundary between Malawi and Tanzania with a buffer of 300m.

3.1 *Data analysis*

The spatial data which is quantitative in nature in form of Geojeson files was be subjected into PostgreSQL (PgAdmin4) Database to generate meaningful data which was analyzed by an Open source GIS software namely Quantum GIS version 3.2, the researcher used PostGIS plug in to derive some meaningful results. A high resolution satellite image was used to authenticate the boundaries and removing topological errors. For the qualitative data, the data was vetted to statistical analysis, the type of statistics that was used in this study was descriptive.

3.1.1 *Responses from MCLMT*

A total of 364 parcels were surveyed using the general boundary principle following the available physical features present on the ground. The location of the land parcel dictated the country of originality in relation to the international boundary line, both actual and perceived international boundary line.

Nationality	Frequency	Percentage
Malawian	285	78.30
Tanzanian	79	21.70
Grand Total	364	100.00
Marital Status	**Frequency**	**Percentage**
Divorced	4	1.10
Married	325	89.29
Single	6	1.65
Widowed	29	7.97
Grand Total	364	100.00
Ownership status	**Frequency**	**Percentage**
As family	42	11.54
Individual	293	80.49
With spouse	29	7.97
Grand total	364	100.00

Nationality	Encumbrance	Frequency	Percentage
Malawi	NO	205	56.32
	YES	80	21.98
Tanzania	NO	45	12.36
	YES	34	9.34
Grand Total			100.00

Figure 2. Demographic Information.

Figure (2) displays the participant's nationality, marital status, ownership status, gender and encumbrances. The table illustrates that the majority of land parcel holders 78.3% are Malawians and 21.7 % of land parcel holders are Tanzanians which implies that the area is dominated by Malawian nationals whose parcels also fall in Tanzania. The table also shows that 89.29% are married while 1.65% are single and 1.10% ,7.97% are divorced and widowed respectively which implies there's a chance of inter-marriages between Tanzanians and Malawians which can also influence the land holding status in terms of land registration due to difference in cultures, in addition the gender shows that 57.69% of land parcels is owned by men while 42.31% is owned by females regardless of where the parcels is falling, this implies that men possess high chances of owning land due to cultural norms that men are the heads of families although in this case there is a thin margin of the difference which shows that there is a migration of norms in recent times in terms of land distribution between men and women. Table 1 also shows that 80.49% prefers to register their land parcels on individual basis while 11.54% registered the land as family land while 7.97% registered with their spouse, this implies that land parcels are basically individualized to maximize security of tenure rather than registering as a group in fear of land conflicts in terms of distribution and usage. There were also encumbrances in both sides of the boundary such as footpaths, boreholes, wells and power lines, as depicted in Table 1, 21.98% and 9.34% in Malawi and Tanzania respectively implies that there is a mixture of land use of agriculture and residential.

3.2 *The existing legislation of land adjudication and demarcation in Malawi and Tanzania*

Table 1. Related land acts of Malawi and Tanzania.

ACTS	COUNTRY	YEAR	SECTION	CLAUSE
Village land Act	Tanzania	1999	Part iv: Section (1) subsection (11)	References to the boundaries of village land in this Part shall be to general boundaries. Subsidiary regulation, part V ss 61(2): in marking of the boundaries the committee shall use boundary markers commonly used in the respective areas including boundary tracks, ditches, fences, sisal, other plants and stones
Village Land act		1999	Part iv: Section (C) subsection 48(a)	Except where the boundaries of and interest in land is registered under any law applicable to the registration of village land, or notwithstanding such registration, the boundaries and interests in land are fully accepted and agreed to by all persons with an interest in that land and in respect of the boundaries of that land and land bordering that land, no grant of a customary right of occupancy shall be made to any person, group of persons or non-village organization unless and until the boundaries of and interest in that land have been adjudicated in accordance with the provisions of this Subpart(Village land act. 1999).
Customary Land Act	Malawi	2016	Part vi Section 37 Subsection (2)	Adjudication shall either be area adjudication or District adjudication Subsidiary regulation Part III (21): A land clerk in liaison with the customary land committee carry out the verification of boundaries of TLMA using an Orthophoto map from the District Land registrar
Land survey act 2016	Malawi	2016	Part VI, section 46(1)	The boundaries of any area Declared as TLMA, a district or a local government area shall be surveyed and registered in the subsequent Land registry Subsidiary Regulation Part XI (91) visible and identifiable natural or man-made features surrounding a piece of land parcel shall be used as a general boundary (95) fixed boundary shall be applied in all boundaries where it is impossible to demarcate land parcels using general boundaries.

In this section, the study aimed to find out how the legislation is framed in Malawi and Tanzania respectively in respect to adjudication and demarcation of land parcels including their subsidiary regulations, the land in question for this particular study is customary land as categorized in the Malawi land act and Village land as described in the Tanzania land act respectively therefore the related acts scrutinized in this study included, land Act, Village land act, Local Government (district authorities) act, Land Survey act from Tanzanian Side and Land act, Customary land act and Land survey act from Malawi side. The acts were analyzed on the specific clauses in regards to the procedure and processes of adjudication and demarcation according to the category of land used in this study. The similarities and differences have therefore been synthesized to develop a framework that works for land parcels that lie between an international boundary in border areas.

3.3 *The extent of land parcels that lie on a common perceived and the actual international boundary of Malawi and Tanzania*

DESCRIPTION	No	AREA (Hectares)	PERCENTAGE
PARCELS ALONG THE PERCEIVED INT BOUNDARY	34	30.22	11.11
PARCELS ALONG THE INT BOUNDARY	35	28.56	10.50
PARCELS PERCEVED TO BE IN MALAWI	11	10.23	3.76
PARCELS PERCEVED TO BE IN TANZANIA	23	19.98	7.35
PARCELS NOT AFFECTED BY THE INT BOUNDARY	261	182.94	67.28
TOTAL LAND PARCELS SURVEYED AND MAPPED	364	271.93	100

The land parcels mapped that are along the international boundary were 35 representing 10.50% of the total land surveyed and it covered a substantial size of land of 28.56 hectares of land, this shows that there is a considerable number of land holders that are affected by the international boundary between Malawi and Tanzania, this entails that their land registration status during the land reform projects will be compromised as their land is falling in between two countries. While those land parcel holders who are perceived to be in Malawi while they are actually in Tanzania is 7.35% covering a substantial land size of 19.98 hectares and parcels perceived to be in Malawi while they are actually in Tanzania stands at 3.76%, covering a total of 10.23 hectares of land, this shows that there is an intermediate level of unawareness of the exact boundary line on the ground. 11.11% is the land that falls within the perceived international boundary as interpreted by the locals surrounding the international boundary line, this shows that the locals are unaware of the actual international boundary.

3.4 *Adjudication and demarcation framework*

The proposed adjudication and demarcation framework for land that falls between countries. The essence of developing the framework is to address the problem of land registration in border areas during mass registration projects in both Malawi and Tanzania. Therefore, the framework provides the land reforms experts undertaking mass registration projects in Malawi (land reform implementation project) and Tanzania (land tenure improvement project) that can be used to register land parcels using applicable legislation to project beneficiaries without escalating conflicts between two sovereign states while securing land tenure for their respective citizenry.

The land parcel that falls between the international boundary of two countries is subjected to two diferent legal tenure systems, therefore the framework below illustrates the proposed framework in which can be adopted for both countries to provide tenure security for the land parcel holders. It has been illustrated in Table 2 according to the CLA and VLA with subsequent regulations that adjudication and demarcation of village land and customary land use general boundary systems which are common for both countries, therefore the framework synthesises the similar approaches for the approaches to grant CCRO's and CEC's respectively to land parcel holders.

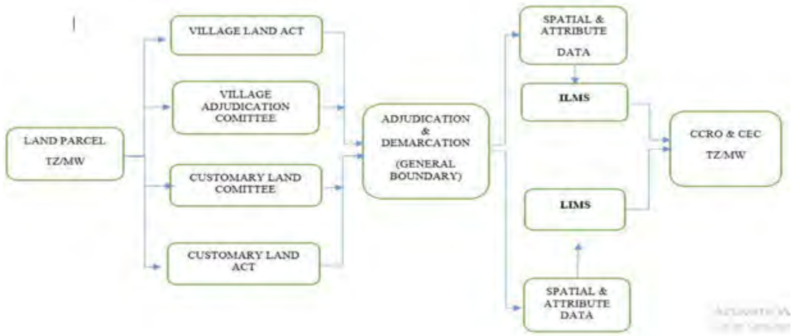

Figure 3. Proposed adjudication and demarcation framework.

The Figure (3) above illustrates that, regardless of which project of the concerned countries embarking on customary/ village land registration, the parcel be adjudicated and demarcated according to the provisions stipulated in the CLA (16 of 2016) and Village land act (CAP 114) respectively in respect to the international boundary line while ensuring the security of land tenure to parcel land holders in presence of Village land adjudication committee, adjudication adviser and neighbours of the concerned land parcel, similary for customary land the adjudication process be done in presence of customary land committee, Land clerk and neighbours of the concerned land parcels using available physical feautures technically known as general boundary principle. The attribute data (name, size, affiliation, nationality, etc) and spatial data (polygon, centroids, features, etc) be recorded and uploaded on the respective land management information systems availabe in both malawi and tanzania namely land information management system (LIMS) and Intergrated land management infromation system (ILMIS). The granting of CCRO's and CEC's can thereafore be applied in respect to area of jurisdiction with the proposed amendments in subsequent regulations to be treated as such.

4 CONCLUSIONS AND RECOMMENDATIONS

The study reveals that the assessment of existing laws and requirements involves a comprehensive review of domestic legislation specifically on subsidiary regulations on the treatment of land that borders two countries as the law is silent on how such land should be treated in terms of adjudication and demarcation for the purposes of registration. The Village land act (VLA) and Customary land act (CLA) provides the benchmark for adjudicating the land in question except special land such as border areas for the jurisdiction in question. The study also unveiled that there are land parcel owners who perceive to hold land in Tazania (7.35%) while their land jurisdiction is Malawi in respect to the international boundary, similary for land holders that percerve land holding in Malawi (3.76%) this depicts the level of unawareness of the actual boundary by the local communities. The study foud out that 10.5% hectares of land is in between the the actual international boundary of Malawi and Tanzania which is significant to develop a framework of ensuring land tenure security for such land parcels.

Therefore the study recommends that while land reform projects are being implemented, a thorough analysis of relevant, bilateral agreements, and domestic legislation pertaining to adjudication and demarcation of land parcels between Malawi and Tanzania should be conducted. Identify any inconsistencies or gaps in the existing legal frameworks and consider the applicability of international law principles to the specific context of the border between the two countries. Engage stakeholders, legal experts, and international organizations to ensure a comprehensive understanding of the legal landscape and explore opportunities for enhancing legal clarity and effectiveness in adjudication and demarcation of land parcels that lie between two countries.

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