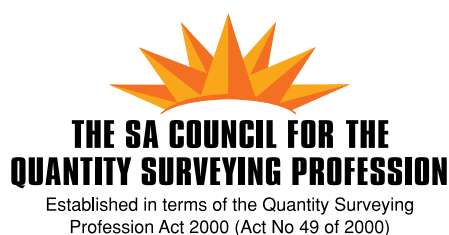


QUANTITY SURVEYING RESEARCH CONFERENCE 2024



**DISRUPTING
TRADITION**

**THE EVOLUTIONARY
CROSSROADS
OF THE QUANTITY
SURVEYING PROFESSION**



**21-22 OCTOBER 2024
KWAZULU-NATAL
SOUTH AFRICA**

**PROCEEDINGS OF THE 14th SACQSP
INTERNATIONAL RESEARCH CONFERENCE 2024**

EDITOR: PROF GERRIT J. CRAFTFORD

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Disrupting Tradition: The Evolutionary Crossroads of the Quantity Surveying Profession

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Prof Gerrit Crafford

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MAIN THEME OF THE CONFERENCE

The principal theme of the conference, "Disrupting Tradition: The Evolutionary Crossroads of the Quantity Surveying Profession," functions as an academic impetus for a critical appraisal of the ongoing and indispensable evolution within the domain of quantity surveying. This theme compels professionals, scholars, and industry luminaries to engage with the swiftly evolving terrains of construction, economics, and technological advancements, thereby interrogating the profession's capacity to either adapt to these changes or risk obsolescence. It advocates for a rigorous examination of the necessity for the quantity surveying discipline to undergo transformation to sustain its relevance, efficacy, and influence amidst burgeoning challenges such as the advent of artificial intelligence, the pervasive influence of the construction mafia, the rise of digitalisation, practices of fee discounting, evolving gender dynamics, shifts in the global economic landscape, issues of delayed payments, the imperative of sustainable development, and overarching transformation imperatives. This theme represents a clarion call for introspective analysis and proactive engagement, prompting a reassessment of entrenched methodologies and the adoption of innovative, flexible strategies poised to redefine the trajectory of the quantity surveying profession.

SUB-THEMES

- Augmented/virtual/mixed Realities
- Big Data and the Construction Industry
- Building Information Modelling and Digital Twin Technology (Bim, Brim, Cim, Gis)
- Business Modelling
- Carbon Emissions and Energy Usage in the Built Environment
- Changing Roles and Responsibilities of Quantity Surveyors
- Circular Economy in Construction
- Commercial Management
- Competitiveness
- Construction Digitalisation and Artificial Intelligence
- Contract Management
- Corporate Social Responsibility
- Data Management
- Digitalisation and Construction Human Resource Management
- Efficient and Sustainable Use of Construction Materials
- Health, Safety, and Well-being of Construction Workers and End-users
- Pedagogical Development/Learning and Teaching
- Professional Ethics
- Regulatory Framework for Government Initiatives
- Risk Evaluation
- Skills Development
- Smart Contract
- Sustainable Construction Practices
- Value Management



FOREWARD - Mr Arthur Quphe

*President of the South African Council for the Quantity
Surveying Profession*

As we gather for this pivotal International Research Conference, we stand at a crossroads of innovation and tradition. The South African Council for the Quality Assurance of Higher Education (SACQSP) proudly welcomes esteemed scholars, researchers, and thought leaders from around the globe.

At its core, this conference embodies our commitment to disrupting tradition in favor of progress. The rapidly changing landscape of higher education demands that we not only honor established practices but also challenge and reshape them. We are tasked with redefining excellence, integrating diverse perspectives, and pushing the boundaries of knowledge to foster an inclusive academic environment.

This year's theme, "Disrupting Tradition," urges us to explore new paradigms, methodologies, and technologies that can enhance the quality and relevance of our education systems. By embracing interdisciplinary approaches and promoting collaboration, we can address the complexities facing academia in a globalized world.

I encourage each participant to engage in meaningful dialogue, share innovative ideas, and consider the transformative potential of our collective research. Let us leverage our diverse backgrounds to construct a future of higher education that is not only resilient but also truly reflective of the societies we serve.

Together, we can create an environment that values creativity, inclusivity, and sustainability, ensuring that our educational institutions rise to meet the challenges and opportunities of tomorrow.

I wish you all an inspiring and fruitful conference.

Warm regards,

Arthur Quphe
SACQSP President



FOREWARD – Prof Nishani Harinarain

Local Organising Committee Chairperson

As the Chairperson of the Local Organising Committee, it is my great pleasure to welcome you to this year's conference, themed *Disrupting Tradition- The Evolutionary Crossroads of the Quantity Surveying Profession*. This gathering represents a unique and timely exploration of how established norms are being challenged, redefined, and ultimately transformed. Our theme invites us to consider new paradigms, question the conventional, and find innovative approaches that can lead to impactful changes within our respective fields.

Technological advancements, shifts in global markets, and societal expectations are prompting us to think differently and adapt with agility and creativity. This conference brings together experts, researchers, and practitioners who are not only observing these shifts but are also pioneering efforts to push boundaries, redefine standards, and inspire transformative change.

The journey to making this conference a reality has been one of collaboration, commitment, and dedication. The organising team has worked tirelessly to ensure a comprehensive programme that is both engaging and thought-provoking. We have been able to create an environment conducive to meaningful discussions and professional growth. My sincere thanks go to each member of the organising team, who have gone above and beyond in planning and executing every detail to make this event possible. I am truly privileged to have led such a dedicated and capable group of professionals.

Special thanks also go to our sponsors, whose generous support has played a fundamental role in the success of this conference. We are incredibly grateful for your investment in this vision and in the future of our field.

Our programme is packed with sessions and discussions that tackle various facets of *Disrupting Tradition*. You'll find presentations that address current challenges, explore disruptive technologies, and suggest practical applications for advancing in a world where adaptability and innovation are key. We hope that these sessions will provide you with not only new knowledge but also inspiration to bring about change in your own work and to continue pushing the limits of what is possible.

I encourage each of you to fully engage in this conference, to network, to ask questions, and to share your own experiences and ideas. Conferences are valuable for the exchange of knowledge, but their real impact lies in the connections we make, the ideas we spark, and the momentum we gain to bring positive change to our work and our communities.

Thank you for joining us, and I look forward to a successful, productive, and inspiring conference.

Warm regards,

Nishani Harinarain
Local Organising Committee Chairperson

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LDM is prepared to lead this transformation. Through our Envision 4.0 strategy, tied to the Fourth Industrial Revolution, we are equipping future quantity surveyors with cutting-edge tools like artificial intelligence and sustainable construction practices. This aligns with our mission to push the profession forward for the next 40 years and beyond.

Disruption isn't just an idea, it's our tradition. Together with the SACQSP community, we will continue breaking boundaries and redefining what's possible in the built environment.

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RLB (previously known in South Africa as RLB Pentad) is part of the global Rider Levett Bucknall brand, and a registered Quantity Surveying and Construction Cost Consultancy that operates across the African continent. The global Rider Levett Bucknall group has 4,300 people, working across 40 countries. This provides us with access to global knowledge, specialist resources, enhanced systems, and an extended client base, which in turn positively contributes to the service that we provide to our clients globally and throughout Africa.

RLB's vision is to be the global leader in the market, through flawless execution, a fresh perspective and independent advice. Our focus is to create value for our clients, through the skills and passion of our people, and to nurture strong long-term partnerships. By fostering confidence in our clients, we empower them to bring their imagination to life, to shape the future of the built environment, and to create a better tomorrow.

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LOCAL ORGANISING COMMITTEE

- **Prof Nishani Harinarain**, SACQSP ESR Committee Member & Local Organising Committee Chairperson
- **Mr Roy Cumberlege**, SACQSP ESR Committee Chairperson
- **Ms Onwaba Tselane**, Registrar of SACQSP
- **Mr Manuel de Bruin**, ESR Manager of SACQSP
- **Prof Gerrit Crafford**, SACQSP ESR Committee Member, Academic Conference Chair & Conference Secretariat

THE LOCAL ORGANISING COMMITTEE'S DECLARATION

All papers in the conference proceedings were double-blind peer-reviewed at abstract and full paper stages by at least two Scientific and Technical Review Committee members as per the peer review process documented on the following page.

THE PEER REVIEW PROCESS

A rigorous two-stage blind peer review process by at least two acknowledged experts in the field for each paper was followed in this conference. The peer review process was strictly adhered to in order to maintain the high standard of the conference proceedings and comply with the requirements for subsidy of the South African Department of Higher Education and Training (DHET).

As part of the review process, each abstract received was twice blind reviewed in terms of the following criteria:

- Academic rigour;
- Coherence, clarity and focus of abstract;
- Originality of the subject matter;
- Relevance to the conference theme, and
- Rigor of empirical research.

Authors whose abstracts were accepted after the first stage of the review process were provided with anonymous reviewers' comments and requested to submit their full papers noting and addressing the comments received. The submitted papers were twice blind reviewed in terms of the follow criteria:

- Academic rigour;
- Appropriateness of research methodology;
- Contribution to knowledge and to industry development;
- Critical current literature review;
- Empirical research findings and robustness of analysis;
- Originality of the subject matter;
- Overall presentation, and
- Relevance to conference theme and objectives.

The final papers were only included in the conference presentation programme and the conference proceedings after evidence was provided of how the double peer-review process's comments had been addressed to improve the papers. At no stage was any member of the Scientific and Technical Review Committee or the editor of the proceedings involved in the review process related to their own authored or co-authored papers. The role of the editor was to ensure that the final papers incorporated the reviewers' comments and arranged the papers into the final sequence as captured on the flash drive and book of abstracts. Of the 90 abstracts originally received, 40 papers were finally accepted for presentation at the conference and inclusion in these proceedings, representing an acceptance rate of 44%. To be eligible for inclusion these papers were required to receive one of three recommendations from at least two reviewers, namely:

- Unconditional acceptance (Exceptional)
- Accepted subject to minor corrections and/or editorial corrections as outlined in the reviewer's report (Above average)
- Accepted conditional upon revision and/or major technical corrections as outlined in the reviewer's report (Average)

Regards,

Prof Gerrit Crafford
Academic Conference Chair

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RELATIVE CONTRIBUTIONS OF ACADEMIC INSTITUTIONS TO THE CONFERENCE PROCEEDINGS

Department of Higher Education and Training
Pretoria
0001

To Whom It May Concern,

RE: RELATIVE CONTRIBUTIONS OF ACADEMIC INSTITUTIONS TO THE CONFERENCE
PROCEEDINGS

The 14th SACQSP International Research Conference was held physically at on 21-22 October 2024 at the Durban Coastlands Umhlanga Hotel, South Africa and the conference proceedings is a publication of selected and presented, peer-reviewed articles.

This letter serves as confirmation that more than 60% of the peer-reviewed contributions published in this conference proceedings emanated from multiple institutions. Consequently, the contributions in the volume meet the requirements for consideration for subsidy.

Should you require any more information, please do not hesitate to contact me at gerrit.crafford@mandela.ac.za.



Prof Gerrit J. Crafford
Editor/Academic Conference Chair

Paper ID	Paper Title	Author 1	Author 1 Affiliation	Author 2	Author 2 Affiliation	Author 3	Author 3 Affiliation	Author 4	Author 4 Affiliation
Paper 001	From Departure to Development: Exploring and Reducing Migration Drivers Among South African Quantity Surveyors	Storm Abbott	Nelson Mandela University, South Africa	Gerrit Crafford	Nelson Mandela University, South Africa				
Paper 003	Analysis of the Impact That Evolving Quantity Surveying Client Services Have on Mining Capital Projects	Binaica Dalpat	University of the Witwatersrand, South Africa	Rolien Terblanche	University of the Witwatersrand, South Africa				
					University of Cape Town, South Africa				
Paper 004	Evaluation of the Circular Construction Knowledge From Quantity Surveyor's Viewpoint	Rotondwa Nemakhavhani	Central University of Technology, South Africa	Josephine Dzansi	Central University of Technology, South Africa	Thabo Khafiso	Central University of Technology, South Africa		
Paper 005	Accounting for Security Expenses: A Built Environment Perspective	Zandré Lambrechts	Nelson Mandela University, South Africa	Nishani Harinarain	Nelson Mandela University, South Africa				
Paper 007	An Evaluation Into the Challenges of the Maintenance Management and Operation: a Case of Eskom Distribution in Limpopo Province, South Africa	Aaron Khumbane	University of the Witwatersrand, South Africa	Rolien Terblanche	University of the Witwatersrand, South Africa				
					University of Cape Town, South Africa				
Paper 008	Driving Digital Transformation in Quantity Surveying: Objectives, Technological Enablers, and Leadership Dynamics	Lisakhanya Bukula	Nelson Mandela University, South Africa	Kristel Van Der Merwe	Nelson Mandela University, South Africa	Gerrit Crafford	Nelson Mandela University, South Africa		
Paper 009	Quantity Surveying Lecturers' Insights into Student Engagement Dynamics	Gerrit Crafford	Stellenbosch University, South Africa	Liesel Frick	Stellenbosch University, South Africa				
			Nelson Mandela University, South Africa						
Paper 012	Effectiveness of the Risk Management Strategies Utilised by Quantity Surveyors in Namibia	Jenin Goagoses	Nelson Mandela University, South Africa	Tirivavi Moyo	Nelson Mandela University, South Africa				
Paper 013	Closing the Loop: Exploring the Quantity Surveyors' Role in Promoting Circularity at the Pre-contract Stage	Anthony Wanyoike	Nelson Mandela University, South Africa	Tirivavi Moyo	Nelson Mandela University, South Africa				
Paper 014	Stressors of Quantity Surveyors in the Eastern Cape	Aimeé Vos	Nelson Mandela University, South Africa	Tirivavi Moyo	Nelson Mandela University, South Africa				
Paper 015	Evaluating Discrepancies Between Existing and Expected Sustainable Construction Competencies Among Namibian Quantity Surveyors: a Pilot Study	Moses Shitataala	Nelson Mandela University, South Africa	Tirivavi Moyo	Nelson Mandela University, South Africa	Roy Cumberlege	Nelson Mandela University, South Africa		
Paper 020	The Impact of Load Shedding on Bulk Water Supply to Metro Municipalities: a Case Study of the Water Sector in Gauteng Province, South Africa	Namhla Rulumeni	University of the Witwatersrand, South Africa	Rolien Terblanche	University of the Witwatersrand, South Africa				
					University of Cape Town, South Africa				
Paper 021	Building New Realities: Enhancing Quantity Surveying and Architectural Education Through Augmented Reality and Virtual Reality Innovations in South Africa	Bogolo Ntombela	Durban University of Technology, South Africa	Mohohlo Tsoeu	Durban University of Technology, South Africa	Sandile Mhlungu	University of Johannesburg, South Africa		
Paper 023	Promoting Construction Education in South Africa: a Single Case Study of the DSI/NRF Research Chair	Clinton Aigbavboa	University of Johannesburg, South Africa	Fortune Aigbe	University of Johannesburg, South Africa				
			CIDB Centre of Excellence & Sustainable Human Settlement and Construction Research Centre, South Africa		CIDB Centre of Excellence & Sustainable Human Settlement and Construction Research Centre, South Africa				
Paper 030	Factors Hindering the Incorporation of Biophilic Design into Hospitals Within the South African Private Sector	Michael-John Dalhouzie	University of the Witwatersrand, South Africa	Mswati Masina	University of the Witwatersrand, South Africa	Bonolo Mathipa	University of the Witwatersrand, South Africa	Rolien Terblanche	University of the Witwatersrand, South Africa University of Cape Town, South Africa
Paper 033	Navigating the Future of Quantity Surveying in South Africa: The Challenges and Benefits of	Nana Gyadu-Asiedu	University of Johannesburg, South Africa	Clinton Aigbavboa	University of Johannesburg, South Africa	Lerato Aghimien	University of Johannesburg, South Africa		

	Integrating Artificial Intelligence into the Quantity Surveying Profession								
Paper 038	The Effects of Late Payments by Government on Building Contractors in South Africa	Zhane Piliso	Nelson Mandela University, South Africa	Roy Cumberlege	Nelson Mandela University, South Africa				
Paper 043	The Use of Digital Technologies to Improve Operations and Maintenance of Public Health Hospitals in KwaZulu-Natal	Nishani Harinarain	University of KwaZulu-Natal, South Africa	Mbongiseni Gcaba	University of KwaZulu-Natal, South Africa				
Paper 044	An Evaluation of the Associated Challenges of Photovoltaic Systems in Residential Units in South Africa	Tafadzwa Chapara	University of Cape Town, South Africa	Rolien Terblanche	University of Cape Town, South Africa				
Paper 047	Assessing the Critical Causes of Construction Contracts Misinterpretation Among Small and Medium Enterprise Contractors	Khaya Rols	Nelson Mandela University, South Africa	Roy Cumberlege	Nelson Mandela University, South Africa	Tirivavi Moyo	Nelson Mandela University, South Africa		
Paper 048	Optimising Dispute Resolution Efficiency and Affordability in South Africa's Construction Sector: a Quantity Surveyor's Perspective	Babalo Maqhutyana	Nelson Mandela University, South Africa	Roy Cumberlege	Nelson Mandela University, South Africa	Tirivavi Moyo	Nelson Mandela University, South Africa		
Paper 050	The Impact of the Black Economic Empowerment Policy on Emerging Contractors in South Africa	Cebile Silinda	University of the Free State, South Africa	Christopher Amoah	University of the Free State, South Africa				
Paper 051	Digital Transformation or Stagnation: Unveiling the Paradoxes of Progress Among South African Quantity Surveyors	Kristel Van Der Merwe	Nelson Mandela University, South Africa	Gerrit Crafford	Nelson Mandela University, South Africa	David Edwards	Birmingham City University, United Kingdom University of Johannesburg, South Africa		
Paper 054	Examining the Implementation of Labour-only Construction Contracts to Bolster Project Execution Within Zimbabwe's Hyperinflationary Context	Mejry Mutsago	University of Zimbabwe, Zimbabwe	Tinoapei Dhlwayo	Namibia University of Science and Technology, Namibia	Tirivavi Moyo	Nelson Mandela University, South Africa		
Paper 055	Assessing Sustainable Construction Competency Gaps Among Quantity Surveyors in Zimbabwe	Rachael Kavukutu	University of Zimbabwe, Zimbabwe	Tirivavi Moyo	Nelson Mandela University, South Africa	Tinoapei Dhlwayo	Namibia University of Science and Technology, Namibia		
Paper 058	Technology-Organisational-Environment Considerations in Implementing Drone Technology on Construction Sites: a Case of the South African Construction Industry	Shadrack Khorombi	University of the Witwatersrand, South Africa	Rolien Terblanche	University of the Witwatersrand, South Africa University of Cape Town, South Africa	Lungie Maseko	University of the Witwatersrand, South Africa		
Paper 064	Effective Strategies for Advancing Sustainable Construction in South Africa: the Issue of Leadership	Zanele Matsane	University of Johannesburg, South Africa	Lebogang Mphela (UJ)	University of Johannesburg, South Africa				
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Paper 072	Evaluating the Effects of Health and Safety Strategies on Social Sustainability in the Namibian Construction Industry	Tinoapei Dhlwayo	Namibia University of Science and Technology, Namibia	Ringisai Dhlwayo	Namibia University of Science and Technology, Namibia	Andreas Shilamba	Namibia University of Science and Technology, Namibia	Trynos Gumbo	University of Johannesburg, South Africa
Paper 076	Adoption of Life Cycle Costing as a Tool in Attaining Best Value: the Namibian Construction Projects' Experience	Ringisai Dhlwayo	Namibia University of Science and Technology, Namibia	Tinoapei Dhlwayo	Namibia University of Science and Technology, Namibia	Kahilu Kajimo-Shakantu	University of the Free State, South Africa	Future Nujoma	Namibia University of Science and Technology, Namibia
Paper 077	Implementation of Artificial Intelligence to Enhance Communication Among Construction Project Stakeholders in Namibia	Ringisai Dhlwayo	Namibia University of Science and Technology, Namibia	Tafara Dziva	National University of Science and Technology, Zimbabwe	Tinoapei Dhlwayo	Namibia University of Science and Technology, Namibia	Kahilu Kajimo-Shakantu	University of the Free State, South Africa

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Paper 085	Impediments to Productivity in Sustainable Construction Projects in Eastern Cape, South Africa: Exploring Construction 5.0 Potential for Improved Productivity Performance	Lukhona Solwandle	Tshwane University of Technology, South Africa	Justus Agumba	Tshwane University of Technology, South Africa	Oluseyi Adebawale	Tshwane University of Technology, South Africa		
Paper 086	Implementing Education 5.0 in the AEC Field: a Living Lab Approach Based on the Quintuple Helix Model	Rudzani Muthelo	Tshwane University of Technology, South Africa	Molebogeng Mogalanyane	Tshwane University of Technology, South Africa				

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KEYNOTE PRESENTATIONS



Nicky Verd - Digital Futurist Keynote Speaker

Nicky Verd is a Digital Futurist, author, international keynote speaker, consultant, and a passionate advocate for personal disruption in an AI-driven economy. As a leading thinker on innovation and digital transformation, she focuses on bridging the gap between people and technology to unlock human potential in the age of disruption. Recognised by Thinkers360 as one of the Top 50 Global Thought Leaders on Digital Disruption and the Future of Work, Nicky Verd inspires individuals to challenge the status quo and reinvent themselves.



Grant Gavin - Entrepreneurial Keynote Speaker

Grant Gavin is a speaker, entrepreneur, coach, and author known for his success in the real estate industry and his influence as a leader. At 27, he acquired a controlling share in a family business and built it into a billion-rand residential property sales company, establishing the No. 1 RE/MAX office in South Africa since 2019. As a public speaker, he focuses on entrepreneurship, sales, and personal development, consistently inspiring others through his principles of servant leadership. Grant founded the Durban Entrepreneurs Club in 2015 and has been an active leader in the Entrepreneurs Organisation (EO), serving as a Regional Director in 2020. His book, "Thoughtonomy," challenges readers to confront limiting beliefs and pursue their full potential, reflecting his passion for personal growth and development.



Abdullah Verachia - Strategist Keynote Speaker

Abdullah Verachia is a globally acclaimed strategist, advisor, and thought leader specialising in strategy, innovation, and disruption. He serves as the CEO of The Strategists, leading a team dedicated to helping organisations craft competitive future strategies. Abdullah is also a senior faculty member at GIBS, head of faculty for strategy, sustainability, and digital, and leads the Harvard Business School Senior Executive Programme for Africa. He has facilitated over 300 high-level strategy assignments for companies and governments worldwide, co-founded disruptive ventures, and played key roles in crafting economic strategies such as the 2017-2030 Gauteng Economic Development Strategy and the Mauritius Competitiveness Foresight Strategy. Abdullah is widely recognised for guiding organisations through complex and turbulent environments.



Lynette Ntuli - Leadership Keynote Speaker

Lynette Ntuli is the Founder and CEO of Innate Investment Solutions, a South Africa-based firm specialising in property, asset, and infrastructure development and management. With over 18 years of experience in the commercial built environment, she has held executive leadership positions across diverse sectors and is a non-executive director on various boards. Lynette was the first woman in Sub-Saharan Africa to be appointed as General Manager of a multi-billion-rand shopping centre (The Pavilion, 2008). She is an internationally recognised thought leader passionate about sustainability, inclusive socio-economic development, and the transformative power of technology. Lynette frequently delivers keynotes and moderates international forums, advocating for leadership, economic inclusion, entrepreneurship, and skills development across Sub-Saharan

Africa.

Accounting for Security Expenses: A Built Environment Perspective

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Abstract

The construction industry in South Africa faces significant challenges concerning security, particularly in combating crime on construction sites. With a focus on using private security to mitigate crime risks, this study investigates security challenges in South African construction, focusing on how modern security costs are priced to enhance cost efficiency. During this qualitative study, eleven interviews were conducted with quantity surveyors, construction contractors, and private security professionals to gain insight into the challenges faced when accounting for security expenses in the South Africa construction industry. The data was thematically analysed to identify trends and themes. The findings highlight that quantity surveyors play a crucial role in managing security costs by integrating various security technologies with strategic planning. Their skill in incorporating security measures early into the budget and evaluating cost-benefit trade-offs ensures projects stay within financial limits while upholding strong security. This approach provides immediate and long-term cost savings and enhances the overall success and safety of construction projects. This paper provides valuable insights into how quantity surveyors can effectively manage security costs in construction projects by integrating advanced technologies and strategic planning, leading to cost savings and enhanced project safety.

Keywords: Crimes, Health and Safety, Quantity Surveying, Security Costs.

Introduction

“Security is a process, not a product” (Schneier, 2015: 273). In the context of South African construction projects, this process has become an indispensable part of the cost structure due to the escalating crime rates. This study delves into the role of the quantity surveyor (QS) in accurately pricing security costs.

The changing dynamics of security in the construction industry reflect a broader shift in understanding security as a dynamic and ongoing process (Nnadi, Okeke & Alintah-Abel, 2020). Within the South African context, the importance of this process is further accentuated by the rising crime rates (Obagbuwa & Abidoye, 2021), which have become a significant factor in the cost structure of construction projects.

The field of quantity surveying, particularly in the South African context, has traditionally been focused on the direct costs associated with construction (Towey, 2017). However, the increasing need for private security on construction projects has added a new dimension to this field (PSIRA, 2024). The significance of this research lies in its timeliness and relevance, as it addresses a pressing issue faced by the construction industry today (PSIRA, 2024).

Current literature on this topic is sparse, with little known about the specific role of a QS in pricing security costs. Previous studies have primarily focused on the broader aspects of cost management in construction projects, with security expenses often overlooked or underestimated.

However, the importance of security in construction projects cannot be overstated. The cost of leaving this issue unresolved could result in budget overruns, project delays, and potentially even loss of innocent lives due to inefficient measures to counter crime (Botrugno, Malagnino, Lazoi & Mangia, 2022).

This study aims to bridge this gap by exploring the role of the construction QS in the context of construction security expenses. It seeks to provide a new understanding of key issues, review and build upon suggestions made by others, and contribute to the theoretical development of the field.

This study endeavours to outline effective practices for managing security costs, thereby enabling a more holistic approach to cost management within construction projects.

Literature Review

The role of security measures on construction projects

In terms of the regulatory framework in South Africa for construction security, the Occupational Health and Safety Act (OHSA) imposes legal obligations on contractors to ensure the safety and security of workers and visitors on site. Compliance with the OHSA, including the provision of adequate security measures, is essential for contractors to avoid penalties and legal liabilities (Department of Labour, 1993).

High crime rates in certain areas make it necessary to invest in strong security measures to protect assets on construction sites. Nnadi, Okeke & Alintah-Abel (2020) highlight the prevalence of crime in South Africa and its direct impact on construction projects. According to Nnadi, Okeke & Alintah-Abel, (2020) a country's high crime rates necessitate the use of robust security measures such as flying drones on construction sites to safeguard workers, equipment, and materials. Private security plays a more significant role in crime reduction than previously thought, sometimes acting as a complement or substitute for police (Blackstone, Hakim & Meehan, 2023).

To comply with the OHSA construction companies are required to implement measures such as access control, surveillance systems, trained security personnel, and emergency response plans to protect their workers and visitors from potential hazards or threats (Ashby, 2017).

A structured approach to evaluating construction site security measures emphasises balancing cost and risk reduction, highlighting the need for regular updates and evaluations of security equipment, personnel, and training programmes to adapt to evolving threats. Understanding security fundamentals helps prevent potential exploitation and ensures appropriate budgeting for security measures (Nemeth, 2022). By assessing the impact of security measures on project costs, Qs can make informed decisions to balance security needs with financial constraints, using cost-benefit analyses and return on investment to ensure efficient resource allocation. Evaluating the cost-effectiveness of security measures is crucial for achieving an optimal balance between security benefits and financial concerns (Dahl, 2021).

Effective security measures for construction projects

Security measures on construction projects are critical to ensuring the safety of both assets and personnel. When considering which security measures to implement, it is essential to evaluate their effectiveness and relevance in the industry. According to Tiwana, Bass, and Farrell (2015), stakeholders must carefully assess which strategies are not only effective but also align with the specific needs and risks of the project.

A variety of security options are available to construction stakeholders. Ma, Zhong, Liu, and Yu (2023) identified several common measures, such as the deployment of security guards, which remains a widely used strategy across many sites. Ashby (2017) further underscores the importance of installing closed-circuit television (CCTV) cameras to monitor activities in real-time, enhancing overall site security. Additional measures, including perimeter fencing, access control systems, and alarm systems, provide layers of security aimed at deterring unauthorised access and detecting intrusions (Kong, Ahn, Seo, Kim & Huang, 2021). However, these systems come with significant costs, which, if not adequately considered during the planning phase, can burden project budgets.

In the South African context, the Private Security Industry Regulatory Authority (PSIRA) plays a vital role in regulating security measures within the construction industry. PSIRA (2024) ensures professionalism and ethical practices by issuing licenses, monitoring compliance, and investigating

complaints. This oversight is critical in maintaining industry standards, particularly in high-risk environments such as construction sites.

Emerging trends in construction security are also reshaping how projects are protected. Technologies like drones and quadcopters are being integrated into security frameworks to provide enhanced surveillance capabilities (Pazzona & White, 2024). The use of K9 units trained to detect weapons during site access checks, along with vehicle stop-and-search procedures, reflects the evolving landscape of construction security. These practices, incorporated into PSIRA's standard training, highlight the increasing complexity of security management on large construction projects. Additionally, the high concentration of private security firm (PSF) headquarters near urban construction sites suggests an expanding infrastructure supporting these security efforts, emphasising the need for Qs and project managers to remain informed of these trends when evaluating the operational costs of a PSF (Pazzona & White, 2024; PSIRA, 2024).

By understanding and integrating both traditional and emerging security measures, construction professionals can develop more robust security strategies that balance effectiveness with cost efficiency, ultimately contributing to the safe and successful completion of projects.

Quantity surveyors' security cost evaluation in construction projects

Quantity surveyors play a critical role in estimating and managing the costs associated with security measures on construction projects. This task is increasingly important given the rising complexity of security risks and the growing expectations for cost-effective risk mitigation strategies. However, there is a gap in the existing literature regarding the specific role of Qs in evaluating security costs, which this study aims to address. By incorporating both cost-benefit and risk management analyses, Qs can more accurately price security measures while ensuring that project budgets remain balanced and efficient.

A common method employed in the evaluation of security expenses is cost-benefit analysis (CBA). This approach provides a quantitative framework to assess the financial implications of implementing security measures by comparing the potential savings from risk reduction with the cost of the measures themselves (Gordon, Loeb & Zhou, 2020). The CBA theory emphasises the need to balance security expenses with the overall project budget to ensure cost efficiency, particularly on large-scale projects where security breaches can lead to significant financial and reputational losses. For instance, evaluating whether investing in more advanced technologies such as surveillance drones is justified by the potential reduction in theft or vandalism is a key aspect of CBA (Jiang & Marggraf, 2021).

In addition to cost considerations, risk management theory plays a pivotal role in shaping the approach to security in construction projects. Risk management focuses on proactively identifying and mitigating security risks to avoid potential disruptions or harm to personnel and assets (Chen & Reniers, 2022). Unlike CBA, which prioritises the financial implications of security measures, risk management theory emphasises the dynamic and evolving nature of security threats, requiring a comprehensive and adaptable approach to managing risks. This theory advocates for the systematic identification of vulnerabilities, evaluating their potential impact, and developing mitigation strategies to protect the project's integrity and safety (Young & Kersbergen, 2019). Integrating these two theoretical approaches enables Qs to develop a holistic and strategic framework for security cost evaluation, minimising the risk of financial overrun while ensuring robust security.

Quantity surveyors must also navigate the complexities of working with private security firms (PSFs), which often hold detailed knowledge of security practices that Qs may lack (Elms & Phillips, 2009). This knowledge gap creates an opportunity for potential exploitation, where PSFs could overprice their services due to the Qs's limited expertise in security contracts. According to Van Riet (2020), Qs may rely too heavily on the contracts provided by PSFs without fully understanding the industry norms and benchmarks, leading to inaccuracies in cost estimation. Addressing this issue requires Qs to develop a basic competency in security management to avoid over-reliance on external security providers and improve their ability to critically assess PSF contracts. When equipped with knowledge of security industry standards, Qs can better estimate the costs of various services, such as private policing, armed response, and site guards, tailored to the specific needs of each construction project (Van Riet, 2020).

The effectiveness of security measures must also be considered alongside cost evaluations. In the South African construction industry, where crime risks are particularly high, evaluating the cost-effectiveness of security measures is a critical task for Qs (Arthur-Aidoo, *et al.*, 2024). The assessment of security guards' performance such as their response time to incidents, ability to prevent unauthorised access, and overall vigilance, can provide valuable insights into whether the security investment is achieving its intended objectives (PSIRA, 2024). This is especially relevant in high-risk environments where both the financial and operational impacts of security breaches can be substantial.

The role of the Qs in construction site security extends beyond merely incorporating security costs into the project budget. By integrating cost-benefit and risk management theories, and by developing a more thorough understanding of the security industry, Qs can significantly enhance their ability to manage security-related expenses effectively, ensuring both cost efficiency and comprehensive protection for construction projects.

Research Method

This research adopted an interpretivist paradigm with an inductive approach to explore the cost estimation practices of Qs for construction security expenses (Saunders, Lewis, & Thornhill, 2016). The use of this paradigm was appropriate for understanding the subjective experiences and perspectives of participants within their professional contexts. Data was collected through eleven semi-structured interviews to provide a rich, in-depth view of how Qs approach the costing of security measures. Semi-structured interviews were selected because they offer flexibility, allowing the interviewer to probe deeper into specific topics while still maintaining a focus on the key research questions.

The data collection took place over a cross-sectional time horizon, with the primary objective of gathering qualitative insights on the methods and considerations Qs employ in estimating security expenses. Non-probability purposive sampling was employed to recruit participants who had relevant expertise in construction security, targeting Qs, construction contractors, and private security professionals. This method ensured that the participants selected had substantial knowledge and experience, allowing for a comprehensive understanding of the study.

To recruit participants, formal invitations were sent via email, which included a cover letter, consent form, and the interview questions. This approach allowed participants to familiarise themselves with the topics to be discussed and prepare for the interviews. The interviews, conducted both via Microsoft Teams and in person, lasted an average of 20 minutes. Participants provided candid and insightful responses, drawing from their unique professional backgrounds, which added depth and authenticity to the data collected.

The data analysis followed a thematic analysis approach, a qualitative method ideal for identifying recurring themes and patterns within narrative data (Terry, Hayfield, Clarke & Braun, 2017). This method facilitated the exploration of common elements across interviews while also allowing for the identification of unique perspectives. The data was manually prepared, coded, and structured, enabling a detailed analysis of the participants' responses. Through this process, key themes related to the costs and practices of estimating construction security expenses were identified and interpreted, enriching the overall understanding of the subject matter.

Research Results

Eleven participants were interviewed, four Qs, four security officers, and three contractors. All the participants were male and they had an average of 14 years experience in the construction industry. Four themes were identified from the data analysis and are discussed below.

Theme 1: Impact of security measures on project costs based on location and risk level

The research revealed a consensus among participants that security measures significantly affect project costs, with variations driven by the location and risk level of the construction site. According to the participants, security expenses typically account for a small fraction of the overall project budget, usually around 1% or less. However, these costs can escalate depending on the complexity and risks

associated with the project. Basic security measures, such as guards and perimeter fencing, are generally cost-effective, but more advanced technologies, such as CCTV, access control systems, and biometric surveillance can reduce long-term costs by minimising the reliance on on-site personnel (Rachamim, Hornik & Ofir, 2023).

Participant B, a CEO of a quantity surveying firm, emphasised that *"security measures include hoarding, site access controls, and advanced technologies like webcams and alarm systems."* The integration of advanced technology can lower overall security costs by reducing person-hours on-site, as seen in cases where technology replaces or supplements physical security personnel. This viewpoint aligns with findings from research conducted by Strom, *et al.* (2010), which highlighted that early incorporation of security costs into project planning, combined with the adoption of technology, can lead to long-term savings through enhanced risk management. For Participant C, a QS, the assessment of security measures must be tailored to the site-specific risks, noting that *"early engagement with private security companies is crucial"*. This ensures that the security requirements, such as site size and project duration, are well understood, and appropriate measures can be implemented.

Several participants agreed that while basic security measures are important, more advanced systems are required for high-risk sites, such as distribution centres. For example, Participant F mentioned that *"companies like Shoprite and Woolworths utilise high-level security infrastructure, including 4.5-meter-high concrete riot walls with electric fencing and barbed wire around their distribution centres"*. Such measures significantly increase the upfront costs, but they are essential in mitigating risks associated with high-value or vulnerable assets.

The importance of management in security cost-effectiveness was a recurring theme. As Participant G noted, *"It's all management. If you don't pay a good manager, the system will collapse. If the manager won't communicate and listen when you need more guards, the project will fail."* This underscores the need for effective leadership in security operations to ensure that security resources are utilised optimally, particularly when more advanced security measures are implemented. Without proper management, even expensive security systems can fail to provide the intended protection. This sentiment reflects the broader perspective that successful security management involves collaboration between project managers, clients, QSs, and community liaison officers, ensuring that the security needs are adequately addressed throughout the project lifecycle.

Participants B, C, F, G, and E each provided nuanced insights into the cost dynamics of construction security, reflecting their distinct roles. Participant F, a private security officer, pointed out that *"security guards are the most cost-effective option, while reaction and tactical teams are the most expensive."* Effective security management requires having a response team on-site to address threats." This was echoed by Participant G, who noted the varying costs based on the type of threat and the location of the project. *"In high-risk urban or industrial areas, more sophisticated systems such as vehicle registration readers and access control technologies become essential, driving up costs."* Both participants also emphasised the inadequacy of basic guards, especially those with minimal training, highlighting the need for *"better training programmes"* to improve their effectiveness.

Participant E, reflecting on the South African context, highlighted that *"security costs are substantial and must be factored into the initial budget,"* with ongoing adjustments based on technological advancements and risk assessments. This perspective aligns with industry findings that advanced security technologies, while costly upfront, can offer cost-efficiency over time by reducing the need for extensive on-site personnel and preventing costly security breaches (Strom, *et al.*, 2010). For instance, high-resolution cameras and biometric systems can reduce long-term security costs by preventing unauthorised access and theft, which are critical concerns in the construction sector.

Ultimately, all participants recognised that advanced security technologies and tailored solutions, though potentially more expensive at the outset, are critical for managing and reducing long-term risks. However, they also acknowledged the importance of site-specific risk assessments, as security requirements can vary significantly based on the location and threat profile of each project. For example, rural sites may only require basic measures, while urban or high-value sites may need advanced and layered security solutions. Therefore, participants agreed that early planning and integration of security costs into the overall budget are essential for balancing short-term expenditures with long-term savings through improved risk management and security technology.

Theme 2: Assessment of risk profiles and security needs

The assessment of risk profiles and the determination of appropriate security measures are crucial factors in ensuring the safety and cost-effectiveness of construction projects. All participants agreed that security measures must be carefully tailored to each project based on the site's specific risk profile, with costs integrated into the project budget. The diversity in approaches reflects the different roles and expertise of the participants. For example, Participant K emphasised the *"difficulties in quantifying the value of third-party security services, especially in high-risk environments."* They noted that *"the biggest cost we face is related to force majeure, particularly time,"* highlighting the financial strain that extended project timelines due to security-related delays can impose. This point underscores the broader industry challenge of balancing security costs with project deadlines, particularly in areas where risks such as construction mafia interference can lead to protracted mediation and increased costs.

Participant D pointed out the unpredictability of security crises, such as hijackings, which can result in significant financial losses, including equipment theft valued at hundreds of thousands of rands. *"Consider the risks associated with the area I'm working in, including potential costs to life, limb, or equipment. For instance, a hijacking could result in the loss of equipment worth R300 000. As a result, the invoicing or quoting for that job should reflect these potential risks, but often the client is unwilling to accept the higher cost."* This observation aligns with the broader industry practice of risk-based costing, where security expenses must reflect the potential losses and vulnerabilities associated with the project location. According to Klick and MacDonald (2023), the principle of deterrence is critical in assessing the likelihood of criminal behaviour by considering the perceived risks and consequences. Private security firms employ similar strategies to estimate the potential security risks and design preventive measures accordingly.

Participants employed a variety of security strategies depending on the specific needs of their projects. Participant A, for example, employed basic security measures such as night guards and electric fencing, adjusting these based on the site's risk profile. Participant B, on the other hand, incorporated more advanced technologies, such as webcams and alarm systems, to enhance security while potentially reducing the reliance on manned security. This view is supported by research from Rachamim, Hornik, and Ofir (2023), who argued that advanced technologies can reduce the need for on-site personnel and, over time, lower long-term security costs. Participant C took a blended approach, integrating fencing, private security, and technology while focusing on community involvement and long-term benefits. This strategic integration of multiple layers of security highlights the importance of early risk assessment and the adaptation of security measures based on the specific vulnerabilities of the project.

The issue of cost management was another recurring theme, with participants offering different perspectives. Participant A viewed security as a small fraction of the overall project budget, whereas Participant B believed that advanced technologies might reduce the cost of manned security over time. Participant C emphasised the importance of early planning for high-risk areas, ensuring that security is not an afterthought but an integral part of the budgeting and tendering process. Conversely, Participants F and G cautioned against cutting security costs, stressing the importance of strategic planning to manage expenses effectively without compromising safety. These varying approaches underscore the importance of tailoring security solutions to the specific risks of each project while maintaining cost efficiency.

Risk management approaches also varied across participants. Participants A and C indicated that they adjusted security measures based on the specific risks of each site, while Participant B integrated security considerations into the initial project bids. This proactive approach aligns with the risk management theory, which emphasises the identification and mitigation of risks throughout the project lifecycle (Chen & Reniers, 2022). Participants F and G stressed the importance of advanced systems and adequate training for security personnel, noting that poorly trained guards can compromise the overall effectiveness of security measures. As Participant E highlighted, *"security requires accurate information, such as a thorough risk assessment."* underscoring the need for informed decision-making based on a detailed understanding of the site's specific risks, including factors such as crime rates, squatter populations, and violence.

Participant G, the owner of a private security firm, discussed the financial challenges of unforeseen security breaches, noting that PSFs sometimes bear the financial burden of such incidents. In one case, the vandalism of a client's truck resulted in a R4 000 deduction from their payment, despite the absence

of a formal contract covering the incident. This highlights the financial risks that PSFs face in the absence of clear contractual agreements, as well as the delicate balance between maintaining client relationships and protecting their own financial interests.

Overall, the participants' insights reflect a strategic and integrated approach to security planning, where risk profiles are carefully assessed, and security measures are tailored to the specific needs and vulnerabilities of each project. While basic security measures may suffice for low-risk sites, advanced technologies and comprehensive security strategies are essential for high-risk environments. Moreover, effective security management requires coordination among stakeholders, including Qs, project managers, and private security firms, to ensure that security costs are accounted for early in the project planning process and adjusted as necessary based on ongoing risk assessments.

Theme 3 Safety versus the costs

Evaluating the effectiveness of security measures in construction projects involves a multi-faceted approach, considering factors such as cost, technology, and management strategies. Participants provided diverse insights into how security interventions are implemented and assessed, with particular attention to the varying levels of risk and their associated challenges. Participant C emphasised the dangers that arise from inadequate security measures, noting that *"re-fencing the site"* was a recurring necessity due to breaches by the local community. This highlights the need for robust access control measures, though even improved systems are sometimes ineffective, as violent confrontations with security personnel have occurred. These incidents illustrate the vulnerabilities of construction sites, particularly when subcontractors are relied upon for security. The limited use of CCTV, except in very high-risk sites, further reflects the trade-offs that are often made based on budget constraints and perceived risk levels.

The issue of organised crime was also raised by Participant A, who experienced interference from gangs. This expands the scope of security challenges, showing that threats range from individual breaches to more organised criminal activities. *"Preventing such incidents requires both proactive security planning and the ability to respond to diverse threat levels."*

Private Security Officers (PSOs), represented by Participants E, F, and G, agreed on the value of advanced security systems such as surveillance cameras and reaction teams. However, they criticised the PSIRA training standards for security guards as inadequate, highlighting the need for well-trained personnel to manage security effectively. This concern resonates with findings from Ariel, Bland, and Sutherland (2017), who demonstrated that increased visibility and focused patrols significantly reduce crime, with victim-generated crimes decreasing by 16% and police-generated detections increasing by 49% in targeted locations. These statistics underscore the tangible benefits of employing well-trained security personnel in high-risk environments.

From a cost-management perspective, Participants F, G, and H discussed the balance between basic security measures, such as guards, and more advanced but costly technologies. Although the upfront costs of advanced systems are higher, they can prevent larger financial losses over time by deterring significant incidents and minimising damage. This approach aligns with Participant E's evaluation strategy, who described the security process as *"trial and error,"* starting with higher levels of security and gradually reducing costs until an incident occurs. This iterative method reflects the dynamic nature of security assessment, where cost optimisation is balanced against maintaining a baseline level of safety.

Contractors, including Participants I, J, K, and M, recognised the high costs associated with advanced security measures, particularly in high-risk areas, where extensive interventions are necessary. However, they stressed the importance of integrating security costs into tender bids and project budgets, with location-specific risks factored into these estimates. Qs play a critical role in this process, as they evaluate the cost-effectiveness of security measures based on risk assessments and historical data from previous projects. Their expertise helps determine how to allocate resources efficiently, ensuring that security measures are both proactive and cost-effective.

The role of technology in enhancing security was further supported by Participant G, who emphasised the need for well-trained guards and advanced surveillance systems in rural construction sites. They pointed out that, in high-risk or remote areas, tracking skills and reaction teams are essential to

maintaining effective security. This view aligns with Katemba (2022), who highlighted the operational success of PSFs in crime prevention, citing their achievements in information sharing, crime mapping, and identifying crime hotspots. The increased capacity of PSFs through training and the use of advanced technology underscores the necessity of continuous investment in security infrastructure to manage evolving risks.

Across all participants, incident prevention and safety enhancement were identified as key metrics for evaluating security measures. Advanced technologies, while more expensive initially, are seen as more effective in reducing security breaches and ensuring site safety. The consensus is that long-term benefits, including lower incident rates and enhanced safety, outweigh the higher initial costs of advanced security systems. Contractors and Qs are instrumental in assessing these costs and incorporating them into project budgets, ensuring that risk mitigation strategies are adequately funded. By doing so, they facilitate the delivery of safer and more secure construction projects, with quantifiable benefits that extend beyond immediate financial savings.

In conclusion, the integration of advanced security systems, supported by well-trained personnel and thorough risk assessments, is crucial for the long-term success of security measures in construction projects. As highlighted by the participants, the effective management of security costs through strategic planning, early budgeting, and the incorporation of site-specific risks, ensures that security measures are both financially sustainable and operationally effective.

Theme 4: The quantity surveyor's role in optimising cost efficiency through security measures

The interviews highlighted that in construction projects, Qs play a pivotal role in optimising cost efficiency, particularly by integrating security solutions into project planning and budgeting. The strategic management of security measures not only ensures that construction sites are adequately protected but also helps minimise long-term expenses. Through a combination of cost-benefit analyses, the adoption of innovative technologies, and the early incorporation of security costs into the planning stages, QS professionals aim to balance effective risk management with overall budgetary constraints.

Participant E highlighted the impact of advanced technologies, stating *"advanced security technology, such as high-definition surveillance cameras and sophisticated access control systems, does increase upfront costs, but it can be more efficient in the long run."* Their firm's experience with these technologies showed that comprehensive monitoring capabilities can reduce the need for as many on-site guards, leading to long-term cost savings. This view aligns with the consensus among QS participants that *"early integration of security costs during the feasibility and planning stages is essential for managing overall project expenses effectively."*

Participant C further emphasised the significance of location in security budgeting: *"The location of the site can significantly impact the budget, so it's important to consider this factor during the feasibility phase early on. For example, projects in high-risk areas may require more expensive security measures, such as control towers at the corners of the site."* This illustrates how site-specific risk assessments inform the selection of security solutions, ensuring that the measures adopted are both contextually appropriate and cost-effective.

However, there are differing perspectives on the costs associated with advanced security technologies. Participants F, G, and H pointed out the higher costs linked to well-trained personnel and advanced security systems, expressing concerns about the adequacy of training for security staff. Despite these initial expenses, they acknowledge the long-term effectiveness of advanced security measures in preventing significant losses from theft or vandalism. This underscores the importance of a long-term perspective in security planning, where initial investments in technology and training are justified by the reduction of future financial losses.

Supporting these insights, Te, Kadar, Rosés Brüngger & Pletikosa Cvijikj (2016) note that sharing crime-related information through security technologies can foster a sense of safety among the public. This aligns with Participant C's advocacy for involving the Community Liaison Officer in security discussions, emphasising a transparent and collaborative approach to security planning.

The role of collaboration is further underscored by Participant E, who emphasised the need for working closely with security technology experts: *"We collaborate with security experts, like those from our own*

firm, to get accurate cost estimates for necessary security services and technology. These estimates are then integrated into the overall project budget, with adjustments made as needed to ensure that security measures are both effective and cost-efficient." This approach reflects a holistic perspective on project management, where expert knowledge is leveraged to ensure cost optimisation and project efficiency.

The optimisation of cost efficiency in construction security requires a careful balance of cost-effective solutions, innovative technologies, and strategic planning. QS professionals are central to this process, ensuring that security measures are not only aligned with project budgets but also contribute to long-term financial savings. By integrating security costs early in project planning, leveraging advanced technologies, and conducting thorough cost-benefit analyses, construction projects can achieve both economic sustainability and enhanced security outcomes.

Discussion

The integration of security measures into construction projects, particularly from a cost-efficiency perspective, is crucial for project success. The study aimed to explore the role of the QS, and while many participants did not express a strong opinion on this role, they provided valuable insights from various positions within the construction security process, contributing to a more comprehensive understanding of the overall landscape. Drawing from the four thematic insights derived from interviews with industry professionals, this discussion evaluates the role of security management, risk assessment, cost-benefit optimisation, and the implementation of advanced technologies. These elements are integral to how Qs and other stakeholders mitigate security risks while maintaining budgetary control.

The first theme highlights that security measures can significantly affect project costs, with variations based on location and risk level. Security expenses, though often a small percentage of the overall budget, can escalate depending on the risk profile of the site. Participants emphasised that basic security measures, such as guards and fencing, are cost-effective in the short term but may be inadequate in high-risk areas. Advanced technologies such as surveillance systems and access control offer long-term cost savings by reducing the need for extensive on-site personnel (Rachamim, Hornik & Ofir, 2023). Moreover, Participant G highlighted that security management must be well-coordinated and adaptable to site-specific risks, underscoring the importance of early integration of security strategies into project planning. This aligns with the views of Strom, *et al.* (2010), who emphasise balancing initial investments with long-term risk mitigation.

The second theme delved into the assessment of risk profiles and the tailoring of security measures accordingly. The varying approaches taken by the interviewees, such as engaging third-party security firms or implementing community-driven measures, underscore the need for contextual adaptability in security planning. The unpredictability of security crises, such as equipment hijacking, necessitates that construction professionals proactively factor these risks into their budget estimates. Klick and MacDonald (2023) support this view by highlighting the importance of deterrence in estimating criminal behaviour and shaping preventive strategies. Effective risk assessment not only ensures the safety of personnel and assets but also provides a financial safeguard against unforeseen security breaches.

The third theme focuses on evaluating the effectiveness of security measures, incorporating perspectives on technology, manpower, and incident prevention. Participants broadly agreed that while advanced security technologies such as CCTV and reaction teams are more expensive upfront, they offer significant long-term benefits in terms of reducing security incidents and protecting assets. Ariel, Bland & Sutherland (2017), for example, found that increased visibility and targeted patrols by private security reduced victim-generated crimes. The approach of trial-and-error security adjustments further emphasises the iterative process of evaluating and refining security strategies to strike an optimal balance between cost efficiency and risk management. This continuous assessment highlights the importance of ongoing collaboration among stakeholders to ensure that security solutions are effectively meeting project needs.

The final theme underscores the role of Qs in cost optimisation by implementing cost-effective security solutions and innovative technologies. As security needs vary greatly depending on the location and risk level of construction sites, QS professionals must engage in early planning to integrate security costs into project budgets (Te, Kadar, Rosés Brüngger & Pletikosa Cvijikj, 2016). This involves cost-benefit analyses that weigh the upfront costs of advanced technologies against their potential to reduce

long-term expenses. This proactive approach helps balance initial investments with potential savings achieved through improved risk management and advanced technology, ensuring that security measures are both effective and financially sustainable.

This study found that Qs play a role in facilitating adequate financial provision for security by incorporating appropriate items in the Preliminaries section of a project's budget. By detailing costs within the Preliminaries, Qs ensure that sufficient funds are allocated to protect the project's integrity and mitigate potential risks.

Moreover, QS participants agreed on the necessity of collaboration with security technology experts to provide accurate cost estimates and ensure that security measures are both financially sustainable and effective. This strategic approach ensures that security is treated not as an afterthought but as an integral component of project planning and risk management. The role of innovative technologies in security optimisation is increasingly recognised, offering long-term savings through reduced manpower and enhanced incident prevention.

Conclusions

The findings demonstrate that Qs are pivotal in ensuring that security measures are not only effective but also cost-efficient, balancing short-term investments with long-term savings.

The ability of Qs to integrate security measures into the project budget early in the planning phase and perform detailed cost-benefit analyses ensures that construction projects not only remain within budget but also maintain a high level of security. This proactive, strategic approach yields both immediate and long-term cost savings, contributing to the overall success and safety of construction projects.

The research demonstrates that integrating security measures into construction project budgets is essential for managing both financial costs and security risks. While basic security provisions such as guards and fencing are seen as cost-effective, the adoption of advanced technologies like surveillance systems and access control mechanisms offers significant long-term savings. These technologies reduce the need for on-site personnel and enhance the project's ability to prevent security breaches.

By incorporating security considerations early in the project planning phase, Qs ensure that budgets remain sustainable while effectively addressing potential security threats. This proactive integration of site-specific risk assessments helps prevent budget overruns by ensuring that necessary security measures are factored into initial cost estimates. The QS's expertise in balancing security needs with financial constraints aligns with the overarching objective of maintaining project financial stability while minimising exposure to risk.

Ultimately, the findings confirm that a strategic, integrated approach to security management, involving early budgeting and the adoption of advanced technologies, is crucial for effective cost optimisation in construction projects. The expertise of Qs in evaluating and incorporating security measures ensures that projects not only remain secure but also achieve economic sustainability. This approach balances risk management with financial efficiency, contributing to the successful delivery of construction projects within the constraints of both time and budget.

Recommendations

To enhance the integration of security measures in South African construction projects, several recommendations are proposed. Firstly, there is a need for clearer standards and regulations governing security practices. Government bodies such as PSIRA should establish guidelines for security assessments, training requirements, and minimum standards for security technologies.

Secondly, improving the training and certification of security personnel is crucial. Comprehensive training programmes should include both technical skills, such as the use of surveillance equipment, and soft skills, such as conflict resolution. Thirdly, Qs and contractors should conduct thorough risk assessments and consider security needs during the feasibility and tendering phases. This proactive approach will help avoid budget overruns and delays due to inadequate security provisions.

Integrating security budgeting into the early stages of project planning is also recommended. Quantity surveyors and contractors should conduct thorough risk assessments and consider security needs during the feasibility and tendering phases. This proactive approach will help avoid budget overruns and delays due to inadequate security provisions.

Lastly, stakeholders should explore the use of advanced security technologies such as CCTV cameras and access control systems. These technologies enhance security and can reduce the need for manned personnel, optimising costs over the project lifecycle.

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Adoption of Life Cycle Costing as a Tool in Attaining Best Value: the Namibian Construction Projects' Experience

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Abstract

Life cycle costing adoption in Namibia seems limited as characterised by poor maintenance and operation of buildings. The study investigates the extent of adopting the life cycle costing to attain the best value for construction projects in developing countries. A quantitative approach was utilised to administer 45 questionnaires to registered architects, engineers, and quantity surveyors randomly sampled in Namibia, and 27 valid responses were received. Data was analysed using descriptive statistics, ANOVA, and correlation analysis to determine the extent of adoption of Life cycle costing. The results indicate that life cycle costing is sometimes adopted for construction projects for best value achievement. The study also found that the proposed measures are moderately effective in increasing the uptake of Life cycle costing on construction projects in Namibia. The study considered Namibia only, limiting the generalizability of the findings to all developing countries. Research should focus on the perceptions of quantity surveyors in other developing countries to obtain a holistic view of the extent of adoption of life cycle costing in other contexts. The study is important to governments, private clients, and professionals for policy reforms, improved project execution principles, and benchmarking of projects for best-value achievement. Life cycle costing has received less attention from the academic side, and this study will generate information regarding the extent of adoption and expected effects of LCC in achieving the best value in the Namibian construction sector.

Keywords: Life Cycle Costing, Developing Countries, Construction Projects, Best Value.

Introduction

Globally, there has been an increase in the adoption of Life Cycle Costing in ensuring cost-effectiveness on construction projects (Manewa, Siriwardena and Wijekoon, 2021) points out that there has been a notable rise in the use of the LCC technique emanating from the introduction of the International Construction Measurement Standards in 2017. Olatunji, Olawumi and Awodele, (2017); Opawole et al., (2020) and Sadliwala and Gogate (2022) have shown an increase in the use of LCC in best-value achievement in several countries including India and Nigeria. However a study by (Kshirsagar, El-Gafy and Abdelhamid, 2010; Anthony Higham, Fortune and James, 2015; Mohd-Rahim et al., 2016) had indicated a slow adoption of the technique in the evaluation of alternative building designs as a broader initiative to best value achievement. LCC application locks value for money interchangeably understood as the best value for money (Olatunji et al., 2017). Consequently, the project team can use the technique to work through several project alternatives to measure the extent to which the best value can be achieved and select the option that maximises the return for the client.

Several factors have been noted to be hindering the application of LCC on construction projects. Olubodun et al., (2010) and Anthony Higham, Fortune and James, (2015) pointed out the "short-termism" philosophy in budgeting of construction projects, lack of awareness of the significance of LCC, lack of reliable data and unstandardised LCC practice as the hindering factors to the implementation of LCC principles on construction projects. Sadliwala and Gogate, (2022) point out that most developers and consultants only consider initial costs at the expense of end-of-life costs. A more elaborative study by (Opawole et al., 2020) shows 47 barriers to the adoption of LCC on construction projects with a lack

of professional experience in LCC; lack of LCC awareness; unstandardised LCC approach; reluctance of the client; project team lack of interest and unreliable data amongst the top-rated ones.

Various studies have been undertaken on LCC and these have addressed myriad views on its use in different countries. Samarasekara, Purushothaman and Rotimi, (2024) undertook a systematic review of literature on the nexus between factors determining LCC calculations on buildings where fifty-one factors were identified. Shibata, Sierra and Hagra, (2023) studied the integration of LCA and LCCA through BIM for optimised decision-making when switching from gas to electricity services in dwellings. Their study found that the application of LCA and LCCA necessitates sustainable and cost-effective decision-making by comparing upgrade costs and energy savings. Other studies have focused on the suitability of the use of LCC in institutional projects (Kshirsagar, El-Gafy and Abdelhamid, 2010), nexus between value for money and techniques to achieve value for money (Olatunji, Olawumi and Awodele, 2017), use of LCC in sustainable construction projects (Sadliwala and Gogate, 2022) and enhanced life cycle cost analysis (Zhivov, 2020). Studies undertaken in the Namibian construction industry focused more on general issues experienced on projects whilst ignoring life cycle costing as a tool for attaining the best value on construction projects. For instance, a majority of the studies in Namibia dwelt on factors affecting cost and time overruns (Mberema and Michell, 2022; Morse and Windapo, 2022; Tjitemisa, 2022). Findings from these studies indicated a lack of proper project/contract management and inadequate planning processes as major impediments to conformance to set time and cost parameters. Other studies in the Namibian Context addressed growth issues and challenges experienced by Small and Medium scale Contractors (Dhliwayo, Musonda and Gumbo, 2022; Thomas and Chirimwana, 2022; Dhliwayo et al., 2024). Therefore, Namibian studies that have been put in the public domain did not address the life cycle costing application on construction projects as a tool to the attainment of best value and that is the gap that will be addressed by this study.

Namibian construction practice relies on initial construction costs whilst ignoring the components of life cycle costs in the selection of projects. Procurement regulations mandate the need to achieve value for money on projects, though life cycle costing is not accorded prominence. For instance, Clause number 14 Section 2 stipulates public entities provide a breakdown of cost estimates after undertaking market research as a measure of guaranteeing the achievement of value for money (Republic of Namibia, 2023). In the year 2023, all 95 projects that the government of Namibia procured were assessed on construction costs alone (Central Procurement Board of Namibia, 2023). Thus, most cost estimates of the procurement plan did not consider the life cycle cost of the proposed projects. The lack of inclusion of LCC in construction cost estimation is a shortcoming to the achievement of value for money on construction projects (Rahim et al., 2014; Olatunji, Olawumi and Awodele, 2017; Sajid et al., 2024). This backdrop has prompted a study to check the extent to which life cycle costing is undertaken to achieve the best value on construction projects in Namibia. This paper presents a literature review on life cycle costing, best value and Life cycle costing process. The paper will also outline the methodology adopted for the study, including the results and discussion. Lastly, the paper will discuss the conclusion and the recommendations.

Literature Review

Life cycle costing

Life cycle costing, or whole-life costing, is an established method of analysing all the costs associated with a project from the inception project to disposal (Cole and Sterner, 2000; Goh and Sun, 2015). Literature shows the components of costs that are included in the LCC calculation (Simion-Melinte, 2014; The European Parliament and the Council of the European Union, 2014; Goh and Sun, 2015; Manewa, Siriwardena and Wijekoon, 2021). Costs include design costs, construction costs, costs during use and costs during reuse costs. Design costs encompass opportunity costs, the cost of preparing feasibility studies, and costs for preparing the technical design and the project execution plan. Maintenance costs, cost of repairs, cost of expected life changes, costs of renewal lifetime and operation costs account for costs during building. Lastly, the costs during reuse are made up of rehabilitation and reuse costs, recycling costs and demolition costs.

Life cycle costing proves to be an important aspect in the evaluation of building costs. Several studies have shown the influence of LCC in enabling correct project decision-making based on different cost aspects of buildings. For example, Cole and Sterner, (2000) Simion-Melinte, (2014) and Zhivov, (2020) indicated that LCC enables a building developer to examine project costs and decide whether it is better

to spend more on construction and enjoy reduced costs of building use and reuse. More particularly, LCC is instrumental in the evaluation of the extent of sustainability in buildings (Goh and Sun, 2015; Ahmad et al., 2024). LCC use has also been witnessed in ensuring quality within the life cycle of buildings (Simion-Melinte, 2014). Thus LCC is useful in ensuring that the correct design option is selected after consideration of the possible savings and expenses associated with each option (Amadi, 2024).

This study argues that the best value may be attained by the inclusion of all these described cost components in evaluations of the best project option to be undertaken. Attainment of best value can only materialise through thwarting unnecessary costs in the project lifecycle (Perera, Barbara and Perfrement, 2009). Ashworth and Perera, (2015) underscores the need to reduce unnecessary project costs in the drive towards the attainment of the best value. Thus best value approach is a prospective way of monitoring the expenditure of the project budget to ensure project cost-effectiveness. Mohd Rahim et al., (2016) points out that best value may be attained through the use of LCC. Olatunji et al., (2017) defines best value/ value for money as the greatest beneficial level of cost, quality, and sustainability appropriate for a defined client. Therefore, this entails that life cycle costing is a tool that is used to partly measure the extent of achievement of best value.

The use of LCC is flawed with a major challenge of its failure to correctly predict costs that are far into the future. the real challenge in lifecycle cost analysis is to obtain accurate comparisons between different design alternatives for the construction of any kind (Kshirsagar, El-Gafy and Abdelhamid, 2010; Samarasekara, Purushothaman and Rotimi, 2024). They concluded in their study that LCC should be used for carrying out cost comparisons of different building designs, types and components in decision-making only rather than in estimating total costs of building facilities. Similarly, Goh and Sun, (2015), point out the influence of LCC in ruling out the prospectives of the attainment of best value on construction projects

In developed countries, the adoption and integration of LCC within construction practices is more extensive than in developing countries. Clients and governments in developed countries emphasise sustainable development and green building trends by considering long-term environmental and economic impacts (Ellingham & Fawcett, 2007). In developed countries, the application of LCC is sophisticated, supported by regulatory frameworks and advanced tools facilitating comprehensive analyses. Moreover, high-profile failures in infrastructure due to neglected lifecycle considerations have propelled LCC as a standard practice in these countries (Messore, Capacci and Biondini, 2021). Moreover, the developed countries have established policies that govern institutions responsible for LCC implementation, for example, Directive (EU) 2023/1791. The advanced economic structure in these countries supports LCC through various financial incentives, the availability of sophisticated LCC tools, and highly specialised professionals. The maturity of LCC in developed countries is such that it extends beyond mere cost calculation. By considering the future impacts of today's construction decisions, LCC practices in these regions contribute to broader sustainable development goals, setting standards that are becoming benchmarks globally (Preiser and Schramm, 2002; Gluch and Baumann, 2004)).

The life cycle costing crocess

Life cycle costing is systematic and involves meticulous steps in collecting and presenting the data to make sound and informed decisions regarding the project. Research indicates that the Life cycle costing process involves discounting all costs associated with a project (Olubodun et al., 2010; Buys, Bendewald and Tupper, 2011). Further, the most problematic area involves forecasting future market conditions such as interest rates, inflation and risk. According to the Royal Institute of Chartered Surveyors (RICS) (2016), LCC comprises four basic steps: defining the brief for analysis of LCC, analysis of the problem, structuring and doing the calculations and validating and interpreting the results. Further, they presented a method of undertaking life cycle costing. Buys, Bendewald and Tupper (2011) pointed out that LCC process commences with establishing a Baseline, definition of the Energy Efficiency Measures (EEMs) calculation of the Financial Metrics and the bundling of Measures. However, this study adopted the LCC process stipulated by RICS (2016) since it is the most recognised institution that governs construction economics operations.

Brief definition involves customising the client's specifications and the project particulars (Orfanidou, Rachaniotis and Tsoulfas, 2023). This forms the inaugural step in the LCC process. This brief is

delineated by understanding the project's scope and establishing the client's objectives for the LCC (RICS, 2016).

Following the articulation of the brief, the subsequent stride entails the examination of the project through data accrual. There is a common agreement that LCC thrives on data accumulation to enable proper calculations. Data encompassing initial expenditures, operational outlays, maintenance charges, and disposal costs, throughout the asset's lifecycle is collected in this phase (Olubodun et al., 2010). Additionally, this phase encapsulates the formulation of assumptions to bridge data gaps and simplify intricate scenarios in LCC calculations (Olubodun et al., 2010; Zhivov, 2020). The step thus ensures a comprehensive consideration of pertinent information and variables, thereby elucidating the problem to be solved through LCC (Khzouz et al., 2020). However, Olubodun et al., (2010) point out that the major hurdle in the generation of data for LCC calculations is the prediction of future market rates of inflation, interest rates and risk exposure. This then undermines the significance of LCC where clients are after precise measurements of future investments.

Analysis of the problem in the LCC process if followed by the next step which involves the execution of calculations. This step establishes a cost model to depict the costs over time, considering all identified variables and assumptions. Future costs are discounted to their present value (Olubodun et al., 2010) and exposed to sensitivity analysis to examine how alterations in key variables or assumptions could influence the outcomes. Hence, LCC analysis considers risk level and uncertainty associated with a project's life costs, consequently providing a robust foundation for informed decision-making (Altaf et al., 2023).

The culminating step in Life Cycle Costing (LCC) entails validating and interpreting the results. Validation is pivotal to ensuring the accuracy, appropriateness and reliability of the computations and the model employed (Gaus et al., 2022). Interpretation of results is embarked upon to glean insights and measure the implications of the LCC analysis (Kambanou, 2020). Consequently, decision-making follows by juxtaposing different options, deliberating risks, and proffering avenues to optimise costs over the lifecycle (Pernetti, Garzia and Filippi Oberegger, 2021).

LCC in achieving best value

Best value is a multifaceted and evolving concept within construction and project management. It endeavours to achieve the most favourable outcome while striking a delicate balance between cost and performance (Mohd-Rahim et al., 2016).

"Best value for money can be defined as the most advantageous combination of cost, quality, and sustainability to meet customer requirements" (Olatunji, Olawumi and Awodele, 2017, p. 55).

Best value therefore endeavours to have an outcome that provides more benefits to the client from the given resources. Hence, if best-value thinking is adopted on construction projects, resources will be saved, and this drives the sustainability agenda to the required level (Rahim et al., 2014).

LCC proposes to achieve optimal long-term investments and thus ensures the 'best value' rather than the lowest initial cost. Studies (Olatunji, Olawumi and Awodele, 2017; Lindholm et al., 2019; Zhivov, 2020). Olatunji claims that the use of LCC can enhance the optimum use of project designs and materials capable of reducing the operational costs of buildings in the long run. LCC is effectively considered at the preliminary project phase by deciding a cost-effective choice on several design options capturing the initial and the costs in use without detriment to the required quality standard. Therefore, based on the definition that has been given previously, the best value is attainable through utilising LCC techniques. These studies show that LCC can be used to determine the level of achievement of best value at the design stage of construction projects. Literature in Namibia does not record the use of this method in determining best value attainment.

Various criteria have been proposed to operationalise the concept of best value on construction projects worldwide. Some studies have focused on the Most Economically Advantageous Tender (MEAT) adjudications (The European Parliament and the Council of the European Union, 2014; Lindholm et al., 2019; Sorte Junior, 2022) as the most common basis to use to ascertain the possibility of best-value achievement at the tender stage. Criteria that are normally used as a basis in adjudications of best value considerations include the lowest total cost of construction, least life cycle costs, quality and

specifications, functionality, performance and also increased returns from projects (Mohd-Rahim et al., 2016; Lindholm et al., 2019; Zhivov, 2020). The European Parliament and the Council of the European Union (2014) pointed out that Meat adjudications should be considered from an LCC basis where the option with the best price-quality ratio is selected by reviewing the previously stated criteria. Other issues considered in the ascertainment of best value include project schedule, eradication of cost escalations, innovation, consideration of maintenance cost in cost decisions, precise forecast of project costs and detailed specifications (Olatunji, Olawumi and Awodele, 2017).

Based on the arguments provided in this section, the best value is crucial on projects as it measures how well resources are used especially on public projects. Thus this study will consider at least possible total construction costs of the project, lowest operating costs of the project, lowest possible total life cycle cost of the project and durability as best value parameters. Minimal repair requirements, highest possible project outcome and realisation of expected project quality were also considered as best value parameters for the study.

Research Methodology and Method

A quantitative approach was adopted to collect cross-sectional data on the extent of adoption of LCC as a tool to attain best value on construction Projects. The study was undertaken in Windhoek, where most of the registered construction consultant firms are based and have enough activity and dynamics to achieve the goals of this research. According to the Namibian Council for Architects and Quantity Surveyors' (NCAQS) 2015 list, 72% of construction consultant firms reside in Windhoek. Windhoek will be able to give insights into the phenomena under consideration. A closed-ended questionnaire was designed based on the literature review conducted requesting respondents to indicate the level with which the different LCC steps are undertaken on construction projects in Namibia, using a Likert Scale of 1 to 5, where 1 is Never; 2 is Rarely; 3 is Sometimes; 4 is Often and 5 is Always. The mean interpretation of the 5-point Likert scale for the extent of adoption of LCC was given as follows: $MSs > 1.00 \leq 1.79$ (Very low extent), $MSs > 1.80 \leq 2.59$ (Low extent), $MSs > 2.60 \leq 3.39$ (Moderate extent), $MSs > 3.40 \leq 4.19$ (High extent) and $MSs > 4.20 \leq 5.00$ (Very high extent). The questionnaire was also used to determine the extent to which best value parameters are attained on construction projects in Namibia. In addition, the mean scores in testing the frequency of best value achievement were also interpreted using the range where: $MSs > 1.00 \leq 1.79$ (indicated a Very low frequency), $MSs > 1.80 \leq 2.59$ (indicated a Low frequency), $MSs > 2.60 \leq 3.39$ (Moderate frequency), $MSs > 3.40 \leq 4.19$ (High frequency) and $MSs > 4.20 \leq 5.00$ (Very high frequency). This study employed stratified random sampling to collect quantitative data from Civil Engineers registered with the Association of Engineering Council of Namibia (AECN), Quantity Surveyors registered with the Institute of Namibian Quantity Surveyors (INQS), and Architects registered with Namibia Institute of Architects (NIA). Consequently, 45 participants were selected for the study and this was deemed acceptable since the respondents were experts. The mean index and range, Analysis of Variance (ANOVA) and Pearson correlation were used to analyse quantitative data (Crawshaw and Chambers, 2001; Bryman, 2012).

Research Results

The study sought to determine the extent of LCC adoption as a tool to Best Value attainment on construction projects in Namibia. This section commences by presenting data on the demographics of respondents and the extent of adoption of Life Cycle Costing (LCC) as a tool for attaining the best value on construction projects in Namibia. Forty-five questionnaires were sent out to the respondents described in the research methodology section and 27 valid responses were returned representing a 60% response rate. The response rate was acceptable for statistical analysis (Moser & Kalton, 1979; Sauro & Lewis, 2016). Quantity Surveyors constituted 45% whilst 22% were constituted by Architects and 33% were constituted by Engineers (Civil, Electrical and Mechanical Engineers). Respondents were also tasked to indicate their experience, and this is shown in Table 1.

Table 1: Experience of Respondents

Experience of Respondents	Frequency
Over 16 years	52%
11 to 15 years	15 %
6 to 10 years	15%
0to 5 years	18%
Total	100%

Table 1 depicts that 52% had an experience of over sixteen (16) years and 15% of the respondents had an experience of eleven (11) to fifteen (15) years and six (6) to ten (10) years of experience respectively. Lastly, 18% of the respondents had 0 to 5 years. Respondents who held national diplomas and bachelor's degrees composed 56% and 7% of the respondents respectively whilst master's and PhD degrees 33% made up 4% respectively.

The extent of use of LCC on construction projects

The objective of this section was to determine the extent to which the LCC process is undertaken on construction projects in Namibia. Respondents were given a table to rank the extent to which the LCC process is undertaken on construction projects. The results are shown in Table 2. Table 1: Extent of Adoption of LCC on Construction Projects

Table 2: Extent of use of LCC on construction projects

LCC Process	Mean	Rank
Calculation of probable construction costs	4.07	1
Identifying the scope of the work that needs to be done	4.00	2
Identifying the client's needs and separating them from their wants	3.63	3
Review and feedback (report findings to stakeholders etc.)	3.04	4
Estimating the likely maintenance costs	3.00	5
Identifying the objectives of the life cycle costing exercises that the client needs	2.96	6
Estimating the likely operational costs	2.89	7
Forecasting renewal costs	2.85	8
Modelling and Calculations (includes data conversion and formulating cost models to depict the costs over time)	2.70	9
Forecasting project decommissioning	2.41	10
Sensitivity/scenario analysis	2.44	11
Mean of LCC process	3.09	

Table 2 shows that two of the steps often undertaken were "Calculation of probable construction costs" with a mean of 4.07 and "Identifying the scope of the work that needs to be done" with a mean of 4, indicating these processes are often utilised. The table also shows that identifying the client's needs...., reviewing and feedback and estimating the likely maintenance costs had mean ratings of 3.63, 3.04 and 3 respectively. This indicates that these steps were sometimes undertaken. The remaining 6 out of 11 steps were rated with means around 2 indicating that they were rarely undertaken on construction projects in Namibia. The mean scores generated in this section of the study were also interpreted by the range which was given as follows: MSs>1.00 ≤ 1.79 (Very low extent), MSs>1.80 ≤ 2.59 (Low extent), MSs>2.60 ≤ 3.39 (Moderate extent), MSs>3.40 ≤ 4.19 (High extent) and MSs>4.20 ≤ 5.00 (Very high extent).

However, based on the mean range the results indicated that 3 out of 11 steps of the LCC process were often undertaken whilst 6 out of 11 steps of the LCC process were moderately undertaken. Two out of 11 steps were undertaken to a low extent. The results are inclined towards a position that indicates a moderate adoption of LCC principles in cost estimation of construction projects. This might also entail a medium achievement of best value on construction projects. The study performed an Analysis of Variance (ANOVA) one factor across the different construction consultants that participated in the study. Table 3 shows the results that were obtained.

Table 2: ANOVA of the extent of adoption of LCC amongst Architects, Engineers and Quantity Surveyors

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.506734	2	0.253367	0.561853	0.576036	3.31583
Within Groups	13.52848	30	0.450949			
Total	14.03521	32				

ANOVA between groups is shown in Table 3 where the F statistic of 0.56183 and the F critical value of 3.31583 were obtained at an alpha value of 0.05. The results indicated no significant difference in the sample means from the Architects, Engineers and Quantity Surveyors regarding the extent of adoption of LCC on construction projects in Namibia. This means that their opinions regarding the extent to which LCC is being undertaken on construction projects are not different.

The respondents were also given a table to rank the frequency with which they experienced the best value parameters adopted from the literature. The data that was collected is shown in Table 3.

Table 3: Best Value Parameters on Construction Project

Best Value Parameters	Mean	Std. Deviation
Least possible total construction cost of the project	3.74	1.163
Lowest operating costs of the project (post-construction)	2.926	.9971
Lowest possible total life cycle cost of the project	2.70	1.203
Increased longevity of the building	3.41	1.083
High Client Satisfaction	3.78	1.188
Minimal repair requirements	3.33	1.144
Highest possible project outcome (desired output) from resources used on the project	3.44	1.219
Expected quality/specifications of outcome	3.37	1.391

Table 4 shows that the respondents moderately experienced six out of eight parameters of best value attainment being considered. This indicates that the best value is being experienced but not at the desirable level sought. Table 3 also shows that the lowest operating costs of the projects and lowest LCC of projects are rarely experienced in Namibia. This either indicates the absence of the LCC process in cost estimation or the highest possible LCC of construction projects. The mean scores were also interpreted using the range where: $MSs > 1.00 \leq 1.79$ (indicated a Very low frequency), $MSs > 1.80 \leq 2.59$ (indicated a Low frequency), $MSs > 2.60 \leq 3.39$ (Moderate frequency), $MSs > 3.40 \leq 4.19$ (High frequency) and $MSs > 4.20 \leq 5.00$ (Very high frequency). Based on the mentioned range, four out of eight parameters of best value were experienced at a high frequency whilst the other remaining four out of eight parameters were experienced at a moderate frequency. The results indicate that the Best value is being attained at a moderate level and this confirms the implication given on the extent of adoption of LCC on construction projects

A further analysis of the correlation between the extent of adoption of LCC on construction projects and the attainment of best value parameters. The study found a correlation of -0.34251 between LCC and Bv implying a weak negative relationship between the two variables under study. This indicates that the moderate extent of LCC being undertaken in Namibia is negatively related to Best Value attainment.

Discussion

The results that have been presented show that more of the respondents are undertaking the calculation of probable construction costs. This implies that all the estimates are being based on the initial construction costs, which form the major portion of the development cost. This resonates with the conventional practice in construction projects, where cost estimation commences by calculating the probable cost of construction (Ashworth and Perera, 2015). Results have also shown that the identification of the scope of works is also often undertaken. The scope of work to be undertaken is also crucial in the LCC process. Each cost level is commensurate to a defined scope of work for a concerned project. This corroborates with the literature that has pointed out that for the achievement of value for money, the requirements of the client need to be identified and these requirements normally stem from the defined scope of the works (Spellacy et al., 2021). Study shows that identifying the client's needs and separating them from their wants is sometimes undertaken on construction projects. It then

indicates that construction projects are being implemented without clarity on what the client requires on the construction projects. Consequently, it indicates that project team members do not have a baseline on what needs to be done and not done to ensure the cost-effectiveness of projects (Olatunji, Olawumi and Awodele, 2017). This is a shortfall that contributes to project failure. Results also show that respondents sometimes review and submit feedback to stakeholders. Reviewing the construction project's costs and sending feedback to stakeholders is an important aspect of the LCC technique which will inform the stakeholders if there is any need to improve some of the components to ensure a certain level of value for money will be attained. This partly contradicts the views of Ashworth and Perrera (2015) and RICS (2016) which advocate for the intensive review of construction costs to improve best value.

Estimating the likely maintenance costs had a mean rating of 3 which means this step is sometimes undertaken on construction projects in the Namibian context. This would be a good practice necessary for the ascertainment of correct project cost giving the client a chance to select a project that has lower maintenance costs (RICS, 2016). However, the results also show that this is not done to a higher extent and thus there is room for improvement. The study also shows that estimation of operational, renewal and decommissioning costs is rarely undertaken on construction projects thereby confirming the assertion of Sadliwala and Gogate (2022). This shows that most of the cost estimations do not consider the LCC. It indicates that the construction industry does not give significance to costs experienced after the construction of a facility, thereby contradicting the views and principles of LCC (Mohd-Rahim et al., 2016; RICS, 2016; Zhivov, 2020). This shows that the Namibian construction industry has not adopted LCC to a full extent. They only implement a few of the important steps of the LCC technique. This partly resonates with the literature that has shown a lack of standardisation in LCC implementation as a major barrier to full implementation of LCC (Olubodun et al., 2010; Opawole et al., 2020). The results also show that modelling calculations and sensitivity analysis are rarely undertaken. It indicates that there are no studies or inferences that are made to cost calculations to test the effect of market or other economic changes on the cost estimations. This corroborates the views of (Perera, Barbara and Perferment, 2009) who pointed out that LCC techniques fail to take cognisance of sensitivity analysis. Again, this points to the low adoption of LCC on construction projects in Namibia.

The study also indicated that there was a fair frequency in the attainment of best value on construction projects undertaken on construction projects in Namibia. This corroborates the findings of (Karunasena and Gamage, 2011; Sayi and Monko, 2022) which shows a considerable level of achievement of best value though more emphasis was put on costs. However, the Namibian experience differs from the Sri Lankan construction industry in that the construction practice in Sri Lanka is mandated by the regulations to undertake value methodology on projects. Namibian experience indicates that the least possible total costs were being experienced at a high frequency in line with the range of Likert interpretation. The lowest life cycle cost of the projects was moderately experienced, which is a positive development though high frequency levels in this aspect could benefit construction projects more. The findings of this study could partly align with the findings of (Akinrata, 2018; Sandaruwan, Chandanie and Janardana, 2021) who was claiming a non-desirable level of LCC adoption by consultants in Sri Lankan and Nigerian Construction industries. Literature shows mixed positions regarding the extent of attainment of best value (de Jong and Arkesteijn, 2014; Bukoye and Norrington, 2015). Dutch construction industry has used best value extensively whilst respondents in Nigeria indicated the non-existence of best value on construction projects. Hence literature partly contradicts the findings of this study.

The correlation between LCC and Best Value was found to be negative and weak. This means the LCC being undertaken on construction projects in Namibia is causing a negative effect on best-value attainment. This entails that the LCC process is not standard, and this corroborates the views of those who postulated that there is a lack of standardisation in the way LCC is undertaken (Olubodun et al., 2010; AP Higham, Fortune and James, 2015). The relatively lower utilisation of processes for estimating operational and renewal costs, along with decommissioning, may suggest a gap in comprehensive lifecycle considerations within the Namibian construction industry.

Conclusion

The study's purpose was to determine the extent to which LCC is implemented to enhance the achievement of value for money on construction projects in Namibia. The results show a low adoption of LCC as a tool to enhance the achievement of value for money on construction projects. This study

also concludes that the inconsistent LCC process being undertaken has a negative poor relationship with the best value parameters. This contradicts the literature that was reviewed from the United Kingdom, United States of America and South Africa. The study concludes that there is also a low attainment of best value on construction projects. The results are significant to the government and construction consultants in formulating strategies that enable the achievement of best value and broader sustainability objectives.

Recommendations

The study recommends the government of Namibia and construction consultant governing boards such as INQS, AECN and NIA institute regulations that mandate all construction projects to implement LCC. Awareness should also be raised on the benefits and significance of LCC on construction projects in best value achievement. The study findings cannot be adopted in all contexts due to the small sample size used. Future studies could enlarge the sample size and include contractors and clients in the study population.

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An Evaluation Into the Challenges of the Maintenance Management and Operation: a Case of Eskom Distribution in Limpopo Province, South Africa

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Abstract

The purpose is to evaluate the efficiency and effectiveness of maintenance management of Eskom electrical distribution and how load shedding and the unbundling of Eskom affect the maintenance performance and effectiveness of the power distribution network. Additionally, the paper aims to answer the sub-question: 'How does load shedding impact the maintenance management and operation of the power distribution network?' The objective is to recommend maintenance management and operation strategies that address these challenges to achieve optimal system performance and improve the distribution network and associated assets. The study used an online quantitative questionnaire survey. The 183 target population of this study are middle managers, line managers, engineers, advisors, supervisors and technicians involved in the maintenance and operation. Ninety-eight usable data sets were obtained, representing a 54% response rate. The study analysed the data using Statistical Package for Social Science (SPSS) software. The research study identifies key challenges such as budget and resource limitations, skilled staff shortages, communication and prioritisation issues, and infrastructure and equipment problems, recommending increased investment in preventive maintenance, enhanced training, improved communication, and strategic planning to optimise operational efficiency and reliability. Load shedding and the unbundling of Eskom affect the power distribution network's performance and effectiveness. Maintenance management and operation also form part of the challenge to achieve good systems and improve the distribution network's performance and associated assets. The research study might apply to the departments responsible for maintaining assets in the public and private sectors. This research's importance lies in its potential to support and propel the adoption of performance-based management principles from an academic standpoint.

Keywords: Maintenance Management, Total Production Maintenance, Lean principles.

Introduction

Eskom the largest provider of electric power in South Africa (SA). These state-owned entity (SOE), in its duties and role as a service provider, has experienced customer concerns regarding its operational efficiency of the electrical infrastructure system. Recently, the entity has implemented stages of power supplier outages, namely load-shedding, due to not meeting the demands of the electricity supplier in South Africa (Pollet, Staffell & Adamson, 2015). In February 2019, South African President Cyril Ramaphosa During the State of the National Address (SONA, 2019) made a much-awaited pronouncement on the future of Eskom. The utility, which is in the depths of a financial and institutional catastrophe, is to be unbundled (Powerfutures, 2019).

The restructuring of Eskom and the introduction of load shedding (Laher et al., 2019) have significantly impacted maintenance objectives of distribution infrastructure (Carnero & Gomez, 2017). The inability to effectively implement existing maintenance strategies for power stations, along with the installation of new electrical systems, has revealed issues such as poor maintenance management and alleged corruption (Laher, Van Aardt, Craythorne, Van Welie, Malinga & Madi, 2019). Network distribution assets comprise key components that require a high level of reliability (Velayutham & Ismail, 2018). To improve maintenance practices, it is essential to adopt a Total Productive Maintenance (TPM) approach (Adesta, Prabowo & Agusman, 2018).

This study aims to investigate the factors that impact the effectiveness of maintenance and operations at Eskom Distribution in Limpopo Province, South Africa. It explores the perceived challenges in managing and maintaining the distribution facility and provide strategic recommendations to improve asset maintenance and operational efficiency.

Literature Review

Operating electrical supply systems

Asset care, good operating electrical distribution power system and reliable source are the important areas in any power distribution industry in advancing countries (Teera-achariyakul & Rerkpreedapong, 2022). The great infrastructure depend solely on the system efficiency and its associated distribution apparatus being well maintained (Msenya, Karugaba & Mgonja, 2022). Considering the efforts by Eskom on load shedding (Goldberg, 2015) and maintaining electrical infrastructure to improve the performance of distribution systems and connected assets, there are still challenges in performing maintenance with a sustainable, unstable disturbance of electrical infrastructure, maintenance and its operation (Morgado et al., 2020).

Alamri et al. (2022) study research focused on evaluating the management of maintenance practices, operational effectiveness, and challenges encountered by maintenance operations in Jordanian power industries. The findings indicated maintenance division facing challenge with its employees, contributing to a lack of experience, encouragement and skills. Both staff and on-the-job training have been the most fitting and effective means for enhancing the capabilities and knowledge of maintenance personnel in their tasks.

The study by Martins, Silva, et al. (2021) brought about effectively integrating various techniques in a construction way and distributing duties and responsibilities on workers. The research objective was enhancing the process managing preventative maintenance within an industry focusing on power and distribution transformers. The results indicated that organising different tools in a orderly way and sharing knowledge and responsibilities with workers resulted in cost savings for the industry, rendering the function of maintenance more efficient (Martins et al., 2021).

The research by Danguche and Taifa (2022) looked on investigating the key factors affecting the successful implementation of TPM in thermal generation plants, gas-fired plants. The study results shows that technical elements, together with scheduled maintenance, planned maintenance, unplanned maintenance, and proactive asset management, had beneficial impact to facilitate the integration of TPM within thermal generation properties. The research finalised that the effective implementation of TPM within energy sector, thermal generation plant, can succeed by taking into consideration management and operation factors.

Study by Quaisie et al. (2020) the objective was to recognise different maintenance methodologies adopted in engineering workshops situated in the western region of Ghana's senior high technical schools. Their study focused in the impact of material and tool management, including the effectiveness of the storage control system, on maintenance practices within engineering facilities. Financial difficulties resulted emerging as a primary difficulty, mainly due to larger capital requirements of the workshop maintenance strategies. In addition, educational institutions lacked proper maintenance training strategies and workshops to train their workshop maintenance workers.

Wakiru et al. (2021) conducted research study alligning maintenance startegies alongside the context of asset performance management (APM) between industries situated in developed and developing nations. The research results indicating both nations, number of factors influenced the implementation of AMPM, alongside lowering maintenance and operational cost, equipment ageing, and return on assets. Difficulties to standardise and the potential loss of maintenance study, which impact the MM of data negatively (Wakiru et al., 2021).

The research conducted by Santos et al. (2019) aimed to implement Total Quality Management (TQM) in the new customer sector of an electricity distribution company in Campos dos Goytacazes, Rio de Janeiro, focusing on three key management pillars: guidelines, processes, and routine. The study

revealed that there is a limited amount of research focusing on Total Quality Management (TQM), particularly when it involves an analysis using the three management levels (guidelines, processes, and routine) within the Brazilian electricity sector (Santos et al., 2019).

The research faced limitations, primarily due to some employees' resistance to the implementation of the tools, and secondly, because the methodology was applied only to one sector of the company.

The effectiveness of maintenance management and operations is critical for ensuring the operational continuity and reliability of infrastructure, particularly in the energy sector. According to Gryphon (1987), the foundational aspects of effective maintenance management include meticulous planning, informed decision-making, and stringent resource control. Bateman and Snell (2002) further emphasise that collaboration and resource allocation are pivotal to managing maintenance activities. In the context of resource management, inadequate budget allocation and skilled staff shortages are persistent challenges, as identified by Morgado et al. (2020). These constraints necessitate a focus on cost-effectiveness and efficiency in maintenance decision-making.

Spare parts availability is another critical concern, as highlighted by Poppe et al. (2018), who underscore the importance of diverse and adaptive maintenance policies. The necessity for adaptive solutions to ensure operational continuity is echoed by Campos and Márquez (2008). Maintenance strategies must evolve to address these challenges, incorporating elements such as predictive maintenance and CMMS. Tsang (2002) and Galán and Gómez (2018) stress the importance of CMMS, such as MAXIMO, in preserving equipment operability and ensuring proper system function. Regular equipment evaluation and predictive maintenance are essential for enhancing availability, reliability, and safety, as articulated by Wang (2007) and Vafaei et al. (2019).

However, mixed responses to cross-training and outsourcing reveal potential concerns within maintenance strategies, reflecting the diverse approaches discussed by Froger et al. (2016). The issue of aging or unreliable equipment is prominent, necessitating regular maintenance to preserve functionality, as noted by Tsang (2002) and Galán and Gómez (2018). Financial, human, and time resource constraints further exacerbate these issues, with Pinto et al. (2020) highlighting the need for constant improvement to maintain financial health and competitiveness. Insufficient employee training and skill development, underscored by Danguche and Taifa (2022), indicate a critical need for enhancing workforce capabilities to effectively address maintenance challenges.

Inadequate management support and poor maintenance quality are additional challenges, emphasising the importance of proper maintenance practices to ensure equipment operability, as noted by Soesatijonoa and Darsinb (2021). Strained supplier relationships and other operational hurdles further complicate maintenance management, necessitating comprehensive strategies such as TPM and RCM. Martins et al. (2021) recommend these strategies to improve asset performance and operational efficiency. The literature also reveals a complex interplay between operational practices and strategic agreements. This divergence reflects in the maintenance literature, where integration into performance objectives for financial success involves various policies like preventative and corrective maintenance (Poppe et al., 2018; Quaisie et al., 2020).

Disparities in perceived maintenance challenges across different job levels further underscore the necessity for tailored maintenance management improvement strategies. This aligns with the literature emphasising the strategic importance of maintenance for organisational success and its critical role in ensuring availability, reliability, and product quality (Wang, 2007; Vafaei et al., 2019). Addressing these challenges requires a comprehensive understanding of maintenance policies and their strategic integration into organisational goals (Gackowiec, 2019).

The practical benefit of this research is that organisations and departments responsible for the maintenance of assets in the public and private sectors could see the importance of managing the maintenance of assets and aligning it to the organisational structure and strategy. This research holds theoretical significance as it has the potential to enhance the current understanding of asset maintenance. Despite efforts to enhance the reliability and health of the electrical infrastructure, gaps remain in achieving sustainable performance. These issues have introduced significant challenges to the maintenance management and operation leading to frequent disruptions and inefficiencies.

The aim of this study is to evaluate the factors influencing the effectiveness of maintenance management and operations within Eskom's power distribution network in Limpopo Province, South

Africa. The study intends to propose viable strategies to enhance the reliability, efficiency, and overall performance of Eskom's distribution infrastructure, thereby mitigating disruptions and inefficiencies. Through this evaluation, the research aims to contribute to the development of sustainable solutions for maintaining and operating the electrical distribution network in the region.

- To determine the factors that influence the effectiveness of the maintenance and operation of the Eskom Distribution in Limpopo Province, South Africa.
- To identify and understand the perceived challenges of the maintenance management and operation at Eskom Distribution in Limpopo Province, South Africa.
- To recommend strategies to improve the maintenance of assets at the Eskom Distribution in Limpopo Province, South Africa.

The order of presentation encompasses an introduction to the research, justification for the problem, offering the literature, research methodology, presenting research results, discussion of findings, conclusion and followed by the recommendation.

Theories

Maintenance Management and Theory: Maintenance management plays an important stage in ensuring the performance and operation of assets. According to Morgado et al. (2020), maintenance management involves setting management responsibilities focusing at achieving maintenance objectives and strategies. These responsibilities involves planning, control, monitoring, and continuous improvement of industry techniques, including economic factors accounting. Maintenance management is split into two fundamental functions: operational and managerial. The operational function demands specific technical skills, whereas the managerial function involves decision-making regarding "what and how to decide" (Pintelon & Parodi-Herz, 2008; Adamu & Winston, 2016).

Management is placed into key functions such as planning, organising, commanding, coordinating, and controlling, Fayol (1949). Griffin (1987) contribute that management contain planning, decision-making, organisation, leadership, and oversight of a industry resources, human, financial, and tangible resources. DuBrin (1994) extend that management is the efficient use of organisational resources to obtain set objectives.

Galán & Gómez (2018) grows on maintenance theory by define it as a comprehensive implementation of administrative, managerial, and technical steps throughout an asset's lifecycle to keep and restore its healthy state. Moubay (1991) shows that maintenance duties ensure the continued functionality of physical apparatus while archiving user requirements.

Maintenance in the Power Industry: In industries such as electrical power, maintenance management is important for operational efficiency. Velayutham and Ismail (2018) indicate the difficulty faced by power plants to inadequate maintenance scheduling, stressing the importance of maintaining an efficient power supply to meet user demand. Maintenance in the power industry, according to Froger et al. (2016), includes both generation plants and transmission infrastructure, with varying time moving from short-term to long-term maintenance activities.

Total Productive Maintenance (TPM): TPM is a technique that involve all levels and functions of a company in maintaining plant asset. Fundamentaly, introduced by Toyota in the 1970s, TPM integrates the maintenance and operation, production departments, encouraging joint responsibility for apparatus care (Bakri, Mahzan, & Latif, 2018). The main goal of TPM is to minimise production losses while achieving optimal quality, cost, and timeliness, with a strong narrowing on equipment reliability (Babu et al., 2016).

Several research have experienced TPM in the manufacturing sector. Prior to its implementation, problem such as high maintenance costs, costly emergency repairs, and significant equipment downtime were largely identified (Gupta & Vardhan, 2016; Galesi-Torres et al., 2020). The initial concept of TPM is to optimise Overall Equipment Effectiveness (OEE) by engaging workers across all organisational levels (Bakri et al., 2018). TPM shares similarities with Total Quality Management (TQM), with regards to employee involvement, cross-functional training, and continuous improvement (Graisa & Al-Habaibeh, 2011; Bakri et al., 2018).

Pillars of TPM and Lean Principles: The TPM methodology is build around pillars, one of which is the 5S system, a Lean tool looking on workplace organisation and cleanliness (Babu et al., 2016). The 5S system is the starting point of the Lean TPM system (Roser, 2021). Fundamentaly developed in response to disorganisation and inefficiency, the TPM model is constructed on the eight-pillar method, which stick total employee involvement and operational efficiency (Ahuja & Khamba, 2008; Sivanantham & Sivaram, 2017).

Research Methodology and Method

This research used a positivist research design with a quantitative approach online survey to evaluate maintenance management and operation challenges at Eskom Distribution in Limpopo Province. A total of 183 employees, including middle managers, first-line managers, engineers, advisors, supervisors, and technicians, were invited from a target population of 337. Using systematic random sampling, 98 usable data sets were obtained, representing a 54% response rate. This sample was deemed sufficient for analysis and reporting of findings. This study employed a non-probability sampling approach, using purposive sampling and used the Statistical Package for Social Science (SPSS) software to analyse the data.

Research Results

An online survey acquired quantitative data from 98 respondents classified the data scores using five-point Likert scales. Normal distribution, median, and standard deviation (Std) calculations were conducted to describe the study's scales' data distribution. Figure 1 indicates that an ideal data of 98 respondents was derived from a sample size of 183 staff members in the chosen study section that including managers, engineers, advisors, and technicians.

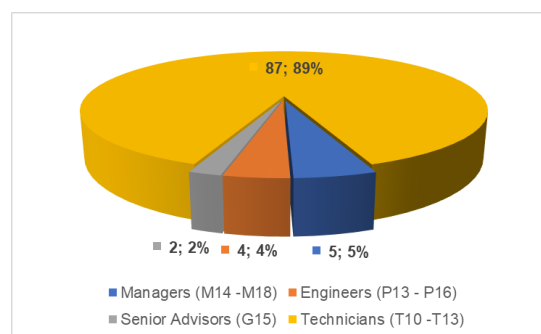


Figure 1: Job level profile of respondents

Questions	1	2	3	4	5	n	Mean	Std	Skewness	Kurtosis
Equipment Breakdowns and Failures	1	10	19	21	47	98	4.05	1.09	-0.79	-0.55
	1%	10%	19%	21%	48%	100%				
Resource Constraints	2	8	9	23	56	98	4.26	1.06	-1.38	1.03
	2%	8%	9%	23%	57%	100%				
Lack of Proper Maintenance Documentation	29	19	12	13	25	98	2.86	1.60	0.18	-1.57
	30%	19%	12%	13%	26%	100%				
Communication Gaps Between Departments	5	16	24	23	30	98	3.58	1.23	-0.38	-0.93
	5%	16%	24%	23%	31%	100%				
High Maintenance Backlog	11	13	21	22	31	98	3.50	1.36	-0.47	-0.97
	11%	13%	21%	22%	32%	100%				
Procuring Spares/Equipment (Procurement):	4	6	11	15	62	98	4.28	1.14	-1.51	1.27
	4%	6%	11%	15%	63%	100%				

Table 1: Maintenance Challenge Severity results (n = 98)

Questions	1	2	3	4	5	n	Mean	Std.	Skew	Kurt
Provision of Training and Skill Development Opportunities for Maintenance Employees	7	21	29	24	17	98	3.23	1.182	-.087	-.868
	7%	21%	30%	24%	17%	100%				
Satisfaction with Tools and Technologies for Managing Maintenance Challenges	19	23	28	24	4	98	2.70	1.160	-.005	-1.003
	19%	23%	29%	24%	4%	100%				
Familiarity with the Concept of Preventative Maintenance	0	2	8	18	70	98	4.59	.730	-1.788	2.538
	0%	2%	8%	18%	71%	100%				
Impact of Loadshedding on Maintenance Operations	16	15	26	13	28	98	3.22	1.433	-.147	-1.250
	16%	15%	27%	13%	29%	100%				

Table 2: Maintenance Management and Engagement results (n = 98)

Determine the factors that influence the effectiveness of the maintenance and operation of the Eskom Distribution in Limpopo Province, South Africa

Resource Constraints: Budget limitations and staffing shortages are significant challenges, impacting the ability to conduct timely maintenance activities and address operational needs effectively.

Procurement Issues: Difficulties in sourcing spares and equipment hinder maintenance operations, leading to delays and increased downtime of critical infrastructure.

Equipment Breakdowns: Frequent failures and breakdowns of equipment contribute to inefficiencies in maintenance processes, requiring reactive rather than proactive maintenance approaches.

Communication Gaps: Interdepartmental coordination and communication gaps lead to delays in maintenance scheduling and execution, highlighting the need for improved collaboration across departments.

Maintenance Backlogs: High backlogs of maintenance tasks affect operational reliability and sustainability, necessitating strategies to streamline and prioritise maintenance activities.

Documentation Challenges: Inadequate maintenance documentation poses a consistency issue, affecting the traceability and effectiveness of maintenance practices.

Technology and Tools: Dissatisfaction with current maintenance tools and technologies suggests a need for upgrades and improvements to enhance operational efficiency.

Training and Development: While training opportunities exist, there is room for further development to enhance the skills and capabilities of maintenance personnel.

Preventative Maintenance: While well understood, the implementation and adherence to preventative maintenance practices can be further optimised to minimise unplanned downtime and extend equipment lifespan.

Impact of Loadshedding: Loadshedding moderately impacts planned maintenance schedules and overall maintenance management, necessitating adaptive strategies to mitigate operational disruptions.

Identifying and understand the perceived challenges of the maintenance management and operation at Eskom Distribution in Limpopo Province, South Africa

The study identified several perceived challenges affecting the maintenance management and operation of Eskom Distribution in Limpopo Province, South Africa. Key issues include inadequate budget allocation, a shortage of skilled staff, and difficulties in effective communication and task prioritisation. These challenges contribute to a complex operational environment where resource allocation, workforce capabilities, and internal coordination are significant hurdles. Particularly critical is the availability of spare parts and equipment, reflecting widespread concern among respondents. Aging

or unreliable equipment poses substantial operational hurdles due to infrastructure deterioration, while resource constraints, encompassing financial, human, and time limitations, impede efficient maintenance execution. Insufficient employee training and skill development further exacerbate maintenance-related obstacles, necessitating enhanced workforce capabilities. Additionally, inadequate management support, poor maintenance quality, and strained supplier relationships emerge as critical areas requiring attention. Addressing these challenges comprehensively is crucial for improving maintenance practices and optimising organisational performance through proactive strategies and continuous improvement efforts.

To recommend strategies to improve the maintenance of assets at the Eskom Distribution in Limpopo Province, South Africa

The research identifies critical challenges in maintenance management, emphasising recurring issues such as inadequate resource allocation, communication gaps between teams, and disruptions during maintenance planning due to power issues. Additionally, concerns regarding insufficient preventive maintenance, difficulty in predicting maintenance needs, and deficiencies in asset tracking are prominently noted. These findings underscore the diverse and complex nature of maintenance challenges, highlighting the necessity for comprehensive strategies to enhance operational efficiency.

Key strategies to improve maintenance management effectiveness emerge from the study's findings. Respondents advocate for increased investment in preventive maintenance practices as a proactive approach to minimise unexpected breakdowns. Enhancing training and development programs for maintenance personnel is also emphasised to bolster workforce capabilities. Moreover, improving communication channels between maintenance teams and operational departments is identified as crucial for fostering cohesive collaboration and reducing operational disruptions. Strategic planning and resource allocation are highlighted as fundamental areas needing improvement to optimise operational efficiency. This includes ensuring adequate allocation of resources to support maintenance activities and enhancing strategic planning processes to align maintenance efforts with organisational goals. Quality management practices are underscored as essential for maintaining high standards across all maintenance operations.

The study emphasises the importance of integrating these strategies within an organisational framework to promote overall effectiveness. By prioritising proactive maintenance planning, routine equipment inspections, and continuous skill development, organisations can enhance operational reliability and minimise downtime. Effective communication and collaboration across departments further contribute to streamlining maintenance processes and ensuring efficient resource use.

Discussion

Findings from the literature

Determine the factors that influence the effectiveness of the maintenance and operation of the Eskom Distribution in Limpopo Province, South Africa

Resource Constraints and Procurement Issues: Gryphon (1987) and Bateman and Snell (2002) underscore the significance of resource management in maintenance operations. Resource constraints, such as limited financial and human resources, pose considerable challenges, affecting the timeliness and quality of maintenance activities. Effective procurement practices are also essential, as delays and inefficiencies in acquiring necessary materials and equipment can exacerbate maintenance challenges. The ability to manage resources efficiently, therefore, is a determinant factor in ensuring uninterrupted maintenance operations and mitigating equipment breakdowns.

Strategic Planning and Policy Implementation: Strategic planning is highlighted as a critical factor by various scholars. De Groote (1995) emphasises the importance of maintenance in long-term financial success, suggesting that strategic foresight in maintenance planning can significantly enhance organisational performance. Tsang (2002) and others argue that maintenance policies, such as TPM and RCM, are crucial for ensuring equipment reliability and functionality. The distinction between planned and unplanned maintenance, as discussed by Campos and Márquez (2008), further informs effective maintenance strategies. Implementing robust maintenance policies can reduce

communication gaps, high backlogs, and documentation deficiencies, ultimately enhancing operational reliability.

Interdepartmental Collaboration: Collaboration between maintenance teams and other departments is a recurring theme in the literature. Effective maintenance management requires seamless coordination across various organisational units. Bateman and Snell (2002) highlight that challenges in interdepartmental collaboration can hinder maintenance efficiency. Enhanced communication and resource allocation between departments are essential for optimising maintenance activities. This aligns with Gryphon's (1987) view of management involving strategic planning and leadership, which is necessary for achieving operational excellence.

Technology and Tools: The use of advanced maintenance tools and technologies is another critical factor affecting maintenance management. Adamu and Winston (2016) suggest that dissatisfaction with maintenance tools can impede the effectiveness of maintenance activities. The literature advocates for the adoption of modern technologies to facilitate predictive and preventative maintenance, thus improving equipment reliability. Tsang (2002) and Vafaei et al. (2019) emphasise that technology can aid in better monitoring and diagnosing equipment conditions, thereby enhancing maintenance operations.

Employee Training and Engagement: Employee training and engagement are vital for successful maintenance management. Regular training opportunities equip maintenance personnel with the necessary skills and knowledge to perform their tasks effectively. Sambrekar et al. (2018) highlight that familiarity with preventative maintenance practices reflects a proactive maintenance culture. Employee engagement in maintenance tasks is crucial for maintaining high standards of operational reliability and performance. The literature suggests that a well-trained and engaged workforce can significantly contribute to the success of maintenance management strategies.

Loadshedding and Operational Disruptions: Operational disruptions, such as loadshedding, pose significant challenges to maintenance management. Campos and Márquez (2008) discuss the impact of such disruptions on planned maintenance activities, emphasising the need for adaptive strategies to ensure asset reliability despite external challenges. The ability to manage and mitigate the effects of operational disruptions is a key determinant of maintenance effectiveness.

Identify and understand the perceived challenges of the maintenance management and operation at Eskom Distribution in Limpopo Province, South Africa

The effectiveness of maintenance management and operations is critical for ensuring the operational continuity and reliability of infrastructure, particularly in the energy sector. Numerous challenges can impede maintenance management, and understanding these challenges is essential for formulating robust improvement strategies. According to Gryphon (1987), the foundational aspects of effective maintenance management include meticulous planning, informed decision-making, and stringent resource control. Bateman and Snell (2002) further emphasise that collaboration and resource allocation are pivotal to managing maintenance activities. In the context of resource management, inadequate budget allocation and skilled staff shortages are persistent challenges, as identified by Morgado et al. (2020). These constraints necessitate a focus on cost-effectiveness and efficiency in maintenance decision-making.

Spare parts availability is another critical concern, as highlighted by Poppe et al. (2018), who underscore the importance of diverse and adaptive maintenance policies. The necessity for adaptive solutions to ensure operational continuity is echoed by Campos and Márquez (2008). Maintenance strategies must evolve to address these challenges, incorporating elements such as predictive maintenance and CMMS. Tsang (2002) and Galán and Gómez (2018) stress the importance of CMMS, such as MAXIMO, in preserving equipment operability and ensuring proper system function. Regular equipment evaluation and predictive maintenance are essential for enhancing availability, reliability, and safety, as articulated by Wang (2007) and Vafaei et al. (2019).

However, mixed responses to cross-training and outsourcing reveal potential concerns within maintenance strategies, reflecting the diverse approaches discussed by Froger et al. (2016). The issue of aging or unreliable equipment is prominent, necessitating regular maintenance to preserve functionality, as noted by Tsang (2002) and Galán and Gómez (2018). Financial, human, and time

resource constraints further exacerbate these issues, with Pinto et al. (2020) highlighting the need for constant improvement to maintain financial health and competitiveness. Insufficient employee training and skill development, underscored by Danguche and Taifa (2022), indicate a critical need for enhancing workforce capabilities to effectively address maintenance challenges.

Inadequate management support and poor maintenance quality are additional challenges, emphasising the importance of proper maintenance practices to ensure equipment operability, as noted by Soesatijonoa and Darsinb (2021). Strained supplier relationships and other operational hurdles further complicate maintenance management, necessitating comprehensive strategies such as TPM and RCM. Martins et al. (2021) recommend these strategies to improve asset performance and operational efficiency.

Disparities in perceived maintenance challenges across different job levels further underscore the necessity for tailored maintenance management improvement strategies. Managers, engineers, and senior-level advisory employees report lower MCA scores compared to technicians, indicating differences in perceived challenges. This aligns with the literature emphasising the strategic importance of maintenance for organisational success and its critical role in ensuring availability, reliability, and product quality (Wang, 2007; Vafaei et al., 2019). Addressing these challenges requires a comprehensive understanding of maintenance policies and their strategic integration into organisational goals (Gackowiec, 2019).

To recommend strategies to improve the maintenance of assets at the Eskom Distribution in Limpopo Province, South Africa

Firstly, strategic maintenance planning is crucial. Effective planning encompasses preventive, predictive, and corrective maintenance strategies, as advocated by industry scholars such as Poppe et al. (2018) and Quaisie et al. (2020). These approaches ensure asset reliability and durability by mitigating unplanned downtime and reducing maintenance costs. Implementing proactive maintenance frameworks, such as TPM, further supports these strategies by fostering a culture of continuous improvement and equipment reliability (Sambrekar et al., 2018).

Secondly, optimising resource allocation is essential. Gryphon (1987) underscores the importance of efficiently managing resources to meet maintenance demands. This involves aligning workforce capabilities and skill development with organisational needs, as highlighted by Alamri et al. (2022). Investing in training programs not only enhances technical competencies but also promotes a proactive approach to maintenance, crucial for minimising disruptions and improving overall operational efficiency (Badhan & Monfared, 2020). Thirdly, fostering cohesive communication and collaboration across departments is critical. Effective communication ensures that maintenance goals are aligned with broader organisational objectives, as emphasised by Hellriegel et al. (2005). Establishing clear channels for information sharing and decision-making enhances responsiveness to maintenance needs and facilitates timely interventions, thereby optimising asset performance and reliability.

Furthermore, integrating quality management practices into maintenance operations is paramount. De Groote (1995) highlights the integration of maintenance goals with overall performance objectives as crucial for achieving operational excellence. By maintaining high standards in maintenance processes and outcomes, organisations can enhance reliability, reduce safety risks, and improve overall operational resilience (Roser, 2021). Lastly, adopting advanced technologies and data-driven approaches supports proactive maintenance management. Robust data management practices enable predictive maintenance, which anticipates equipment failures and reduces maintenance costs (Ahuja & Khamba, 2008). Leveraging technologies like Lean manufacturing and TPM's 5S technique enhances efficiency and reduces waste, aligning maintenance practices with lean principles to achieve sustainable operational improvements (Pinto et al., 2020).

Conclusion

Conclusions for determining the factors that influence the effectiveness of the maintenance and operation of the Eskom Distribution in Limpopo Province, South Africa

To enhance maintenance management and operations at Eskom Distribution in Limpopo Province, strategic interventions are necessary to address resource constraints, procurement challenges, and

equipment breakdowns. Effective resource management, collaboration, and strategic planning are vital for long-term financial success and equipment reliability (Gryphon, 1987; Bateman & Snell, 2002; De Groote, 1995; Tsang, 2002; Galán & Gómez, 2018; Soesatijonoa & Darsinb, 2021; Wang, 2007; Vafaei et al., 2019). Addressing communication gaps and operational deficiencies through improved interdepartmental collaboration and resource allocation is essential (Poppe et al., 2018; Campos & Márquez, 2008; Bateman & Snell, 2002). Proactive employee engagement in preventative maintenance, despite moderate training opportunities and some dissatisfaction with tools, indicates a potential for improvement (Sambreakar et al., 2018; Adamu & Winston, 2016). External factors like loadshedding necessitate adaptive strategies to maintain asset reliability (Campos & Márquez, 2008).

Conclusions for identify and understand the perceived challenges of the maintenance management and operation at Eskom Distribution in Limpopo Province, South Africa

Improving maintenance management and operations at Eskom Distribution in Limpopo Province requires strategic planning, effective resource allocation, and adaptive solutions to address challenges like aging equipment and skill shortages. Key strategies include implementing preventive and corrective maintenance, integrating CMMS like MAXIMO, and investing in continuous employee training. Addressing perception disparities among managers, engineers, and technicians is crucial for aligning maintenance strategies with organisational goals. Proactive maintenance practices, such as TPM and RCM, are essential for enhancing asset performance and operational efficiency, ensuring long-term organisational effectiveness and resilience.

To recommend strategies to improve the maintenance of assets at the Eskom Distribution in Limpopo Province, South Africa

Improving maintenance management at Eskom Distribution in Limpopo Province requires strategic planning, effective resource allocation, and enhanced communication. Key areas include investing in employee training, integrating maintenance into overall performance objectives, and fostering interdepartmental collaboration. Adopting TPM principles and Lean manufacturing can enhance efficiency and reduce downtime, contributing to long-term asset reliability and operational sustainability. Robust data management and continuous improvement are also crucial for effective predictive maintenance and safety standards.

Recommendations

To optimise resource allocation for maintenance activities, management should implement a structured approach that includes upgrading procurement processes to ensure the timely acquisition of necessary equipment and materials, thereby minimising downtime and enhancing operational efficiency. Develop and implement tailored training initiatives for maintenance staff at all levels, focusing on enhancing technical skills and promoting a proactive approach to maintenance tasks. Regular training sessions should be conducted to keep employees abreast of technological advancements and best practices in the field. Foster a culture of collaboration between maintenance teams and other departments by establishing clear communication channels and collaborative frameworks to streamline maintenance workflows and address operational challenges collectively.

Integrate advanced maintenance management systems, such as CMMS and predictive analytics tools, to enable proactive maintenance scheduling based on real-time data, improving equipment reliability and reducing unplanned downtime. Encourage ongoing evaluation and refinement of maintenance strategies by implementing feedback mechanisms and performance metrics to monitor the effectiveness of maintenance practices and identify areas for continuous improvement. Ensure that maintenance objectives align with broader organisational goals, such as reliability, safety, and cost-effectiveness, and develop strategic plans that prioritise maintenance as a critical component of operational excellence and organisational resilience.

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An Evaluation of the Associated Challenges of Photovoltaic Systems in Residential Units in South Africa

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Abstract

In South Africa, the surge in the adoption of solar home systems, driven by frequent load shedding, has resulted in an influx of companies engaged in the sales and installation of these systems. A notable challenge has emerged as varying lifetimes of solar home systems among different installation companies indicate potential quality issues. The main challenges in the operability of solar home systems stem from two primary issues: incorrect design and installation and system reliability. These issues are primarily caused by inaccurate load estimation and limited expertise in solar power systems. The study aims to determine the challenges homeowners face owning solar photovoltaic (PV) systems in residential settings across South Africa. The study aims to interview nine homeowners with a PV system and includes responses from two individuals who completed questionnaires. The data will be analysed using thematic analysis to generate theory-building findings. Semi-structured open-ended questions were asked. The study found several key challenges faced by residential solar system owners in South Africa. Installation and setup difficulties are prevalent, with many systems being installed incorrectly and not optimised, leading to excessive reliance on the grid. Technical and equipment issues further impact system performance. Other challenges are financial and operational, user experience and understanding, support, and service. A small sample and an interpretivistic philosophy limit this study. Future studies should focus on testing a larger number of systems regarding reliability and cost-benefit. Understanding the unique challenges and reliability issues solar adoption presents in this context can pave the way for tailored policies and initiatives. Addressing the challenges of solar systems contributes to the shift from traditional energy practices, and this evolution is essential for modernising residential energy solutions. Finally, if reliability is addressed, then the cost-benefit could be a more accurate calculation, which is essential in the QS profession. While the benefits of solar panels are well known, it is unknown if the installed systems are living up to the desired practical and cost-saving expectations due to the lack of experts in the field.

Keywords: Home Solar, Load Estimation, Load Shedding, PV System, Reliability.

Introduction

The global demand for electric energy continues to rise steadily as countries undergo development, becoming an essential component of modern life. Historically, a large fraction of energy was derived from non-renewable sources, primarily fossil fuels. However, there has been a notable shift towards renewable energy sources in recent years, (Pehl, Arvesen, Humpenöder, Popp, Hertwich & Luderer, 2017). This transition is mainly driven by concerns over heavy pollution, significant carbon emissions, and the accelerated depletion of fossil fuel reserves. Renewable energy offers a promising alternative, characterised by lower pollution levels and reduced carbon emissions.

Various studies have compared greenhouse gas emissions between solar and fossil fuels. Solar systems are noted for producing zero emissions during operation, while approximately 98% of fossil fuel plants generate greenhouse gases during their operational phase. (Kizilcec & Parikh, 2020). Additionally, it's important to note that while solar systems themselves produce zero emissions during operation, greenhouse gases are generated during their production and recycling processes. Components such as PV panels, batteries, wiring, and other modules contribute to emissions during manufacturing and disposal. Therefore, a comprehensive Life Cycle Assessment (LCA) is conducted to understand the total CO₂ emissions produced throughout the life cycle of solar systems, accounting

for both operational and manufacturing/recycling phases. (Pehl et al., 2017). This holistic approach provides a more accurate assessment of the environmental impact of solar energy compared to fossil fuels. These assessments found that solar systems produce approximately 46gCO₂e/kWh, whereas coal technology emits around 164 gCO₂e/kWh and above. (Islam, Al Mamun, Ali, Ashique, Hasan, Hoque, Maruf, Al Mansur & Shihavuddin, 2024).

In South Africa, fossil fuels still dominate in the generation of electricity because renewable energy plants are capital-intensive, less efficient, and limited availability of technology. (Masinga & Madzivhandila, 2023), outlines that South Africa is failing to meet the current demands of electricity leading to load-shedding. Eskom, (2024) describes load-shedding as “A controlled process that responds to unplanned events to protect the electricity power system from a total blackout”. The average time of power outage is 4hrs* and gets worse as the stages increase up to 8 hrs. Some of the challenges posed by load shedding are disruption of daily routine, food spoilage, and reduced security due to electricity-dependent systems being offline, (Masinga & Madzivhandila, 2023). This has led to an increased adoption of solar systems to reduce load shedding.

In South Africa, the surge in the adoption of solar home systems, driven by frequent load shedding, has resulted in an influx of companies engaged in the sales and installation of these systems. However, (Mulaudzi, Bull & Makhado, 2022), notes that there has been a notable challenge emerging as varying lifetimes of solar home systems among different installation companies indicate potential quality issues. A study by (Campana, Holmberg, Pettersson, Klintonberg, Hangula, Araoz, Zhang, Stridh & Yan, 2016), supports the argument by outlining the main challenges in the operability of solar home systems. The challenges stem from two primary issues: incorrect design and installation. These issues are primarily caused by inaccurate load estimation and limited expertise in solar power systems. As a result, diverse faults are present, leading to unexpected shutdowns and raising concerns about the overall quality of the solar energy market.

The increasing use of solar energy in residential contexts poses significant challenges for homeowners, as they often encounter issues related to system reliability, maintenance complexities, and economic viability, (Mulaudzi et al., 2022). Insufficient support structures and understanding exacerbate these difficulties, hindering homeowners from effectively managing and deriving benefits from their solar installations. Previous research on solar energy has largely focused on commercial-scale systems, often neglecting the unique challenges faced by residential solar adopters. This gap in the literature raises a critical question: What operational challenges are being faced by residential solar system owners, and how reliable are these systems? This research aims to fill this gap by investigating the specific challenges that residential solar system owners face and assessing the reliability of these systems, thereby providing a comprehensive understanding that has been missing.

Studying the challenges and reliability of solar energy in residential areas of South Africa holds significant importance due to its potential to alleviate energy shortage, reduce reliance on fossil fuels, and promote sustainable development in the region, (Campana et al., 2016; Mulaudzi et al., 2022). Leaving this unresolved, could result in continued energy shortages, increased reliance on fossil fuels, and missed opportunities for sustainable development. Understanding the unique challenges and reliability issues presented by solar usage in this context can pave the way for tailored policies and initiatives to accelerate its widespread implementation and maximise its socio-economic benefits. Additionally addressing these challenges will instill greater confidence and facilitate the successful adoption of sustainable energy practices among solar homeowners.

The primary aim of this study is to determine the challenges homeowners face owning solar PV systems in residential settings across South Africa. To address this, the study's objectives are to identify the specific challenges homeowners experience with photovoltaic systems, examine system reliability as a significant challenge, and investigate factors that affect reliability. Through this comprehensive assessment, the research will provide a deeper understanding of the operational challenges associated with solar PV systems in residential areas. The significance of this research lies in its potential to inform homeowners, policymakers, and industry stakeholders about the practical challenges of adopting solar energy, thus contributing to more sustainable and effective solutions for residential solar systems in South Africa.

Literature Review

As South Africa faces ongoing energy shortages and rising electricity costs, solar power has emerged as a critical alternative for residential energy solutions. However, while adoption rates of photovoltaic systems have grown, homeowners continue to encounter significant operational challenges that impact system performance and reliability.

To understand the challenges residential solar PV system owners face in South Africa, it is essential to start by examining the different types of solar systems. Additionally, reviewing the challenges encountered by users in the past offers insights into recurring issues, such as system inefficiency, maintenance difficulties, and financial constraints. The following section addresses the current potential challenges homeowners face. Lastly, a brief overview of government initiatives aimed at promoting solar PV adoption will be provided.

Types of solar system

Off-grid PV coupled with Battery Energy Storage System (BESS) systems, also known as standalone PV systems, harness solar radiation using photovoltaic panels. These panels convert solar energy into direct current (DC), which is then converted into alternating current (AC) by converters. The generated AC power is stored in the BESS for later use. According to (Adebanji, Atoki, Fasina, Adetan & Abe, 2021), the term "off-grid" is attributed to these systems because they operate independently of the main power grid, providing electricity to remote or isolated areas where grid connectivity is unavailable or unreliable.

Adebanji et al., (2021), describe grid-connected (PV) systems as systems that harness solar radiation using photovoltaic panels. These panels convert solar energy into DC, which is then converted into AC by converters. The generated AC powers local loads while also feeding surplus energy into the main power grid for distribution to other interconnected users. This setup often includes a centralised grid-connected PV system, where ground-mounted PV arrays function as a centralised power source, supplying electricity to the grid for widespread distribution. Hybrid solar systems combine elements of both off-grid and grid-connected systems, (Adebanji et al., 2021) These systems use photovoltaic panels to generate DC, which is converted to AC for immediate use or stored in a Battery Energy Storage System (BESS). Hybrid systems can operate independently of the grid. They can also feed surplus energy into the main power grid.

The systems described above offer different benefits, and careful consideration is essential before installation. It is crucial to determine the type of system that best meets the consumer's needs. The design team should recognise that most consumers are not well-versed in solar systems, necessitating thorough questioning to account for various scenarios.

Challenges identified in previous research

(Dike, Opara-Nestor, Amaechi, Dike & Chineke, 2017), identified five critical factors contributing to the failure of PV systems in Nigeria: poor system design, substandard products, inadequate planning, lack of maintenance, and high costs of proper equipment combined with a lack of professionalism. These factors not only lead to system failures but also serve as potential indicators of the challenges faced by PV solar system owners.

Poor system design

Poor system design highlights a significant challenge in ensuring that PV systems are tailored to specific needs and environmental conditions. System owners often struggle with inefficiencies due to incorrect component sizing, improper layout, and inadequate consideration of site-specific variables like shading. (Karandikar, Repins, Aznar, Gokhale-Welch, Anand & Khanna, 2020), emphasis on low prices and lack of quality standards drive installers to use subpar products, leading to poor system design. Furthermore, Karandikar et al 2020 study indicated the widespread use of low-quality, sub-standard solar products, particularly in India. As a result, these PV solar systems deliver less energy than expected, deteriorate quickly, or have shorter lifespans. The prevalence of substandard products highlights the challenge of accessing high-quality solar panels, inverters, and other components. PV system owners often face reliability issues and premature failures due to the inferior quality of products available in the market.

According to (Dike et al., 2017; Karandikar et al., 2020), this issue is exacerbated by the high cost of quality products. Furthermore, consumers with limited knowledge of PV solar equipment struggle to distinguish between high-quality and low-quality products. The push towards low-cost installations tempts installers to use subpar products to maintain their profit margins, further promoting the use of inferior components.

PV panel failure and maintenance issues

PV panel failure and lack of maintenance pose significant challenges to sustaining the optimal operation and longevity of PV systems. Many owners lack access to regular maintenance services, leading to system component deterioration. Faults in power plants reduce PV system efficiency and reliability, with failures categorised into optical degradation, electrical inadequacy, and unclassified faults, (Orosz, Rassölkin, Arsénio, Poór, Valme & Slesiz, 2024). Maintenance issues vary by climate: dust accumulation in arid regions, salt-induced corrosion in coastal areas, mold in humid regions, and thermal stress in extreme temperatures. Panels near the ground face shading from overgrown vegetation, and bird or bat collisions can cause cracks. Hail damage can lead to significant performance loss, as seen in Johannesburg in July 2023 (Nkonki, 2023). Accumulated dust, bird droppings, and snow also reduce performance. While PV panels are expected to last 25 years, these issues can significantly reduce their lifespan, increasing maintenance costs and making ownership potentially more expensive than grid electricity.

Battery related issues

Various types of batteries can be coupled with PV systems as energy storage solutions, each offering distinct specifications due to the diverse technologies employed. (Dell, Rand, Connor & Bailey, 2001), provides a comprehensive overview of battery technologies, their applications, and the principles behind their operation. It highlights that while lithium-ion batteries offer higher Depth of Discharge (DoD) of 80-90%, longer lifespan, and greater capacity utilisation, they are more expensive and require advanced management systems to prevent issues like thermal runaway. On the other hand, lead-acid batteries are more cost-effective initially but have higher maintenance needs and shorter lifespans.

Despite their higher cost, lithium-ion batteries offer better performance and efficiency, which can offset the initial expense over time. Research (Ma, Jiang, Tao, Song, Wu, Wang, Deng & Shang, 2018; Önen, Firat & Okutucu, 2023), indicates that operating batteries above their normal temperature range (0°C to 55°C) accelerates aging and reduces their lifespan. This thermal aging issue affects various types of batteries, including lead-acid, gel, and AGM. Batteries need to be stored in a cool, dry place with good air circulation to prevent overheating. However, some users tend to cover batteries in cases, which can increase the temperature as the battery charges and discharges, potentially accelerating thermal aging. All battery types require careful maintenance and adherence to optimal operating conditions to ensure longevity and efficiency. Neglecting these conditions increases maintenance costs, decreases system performance, and can ultimately render the system ineffective.

Safety concerns

Thermal challenges are common in PV systems involving lithium solar batteries. (Ma et al., 2018), describes the operation of these batteries including dynamic processes such as charging and discharging cycles, which inherently generate heat. Studies (Ma et al., 2018), have shown that solar batteries suffer from thermal degradation, making it essential to maintain an optimal operating temperature range to maximise energy conversion efficiency within the battery cells. Temperature extremes can impede chemical reactions, leading to diminished overall performance and reduced energy storage capacity. Additionally, excessive heat accumulation can accelerate the degradation of battery components, ultimately shortening the lifespan of the solar battery. Prolonged exposure to elevated temperatures can have deleterious effects on battery life, efficiency, and, most critically, safety.

Intermittent power generation

These systems depend heavily on sunlight for optimal performance, making intermittent power generation a significant issue. Reduced solar irradiance, such as during cloudy days, nighttime, and winter when sunlight hours are shorter and the sun is farther away, directly lowers power output. Solar energy is inherently variable due to weather conditions, time of day, and seasonal changes. This intermittency can lead to periods of insufficient power generation, affecting the reliability of the systems.

Current challenges faced by solar system owners in South Africa

Despite the implementation of a new government policy aimed at promoting the adoption of solar systems, there remain challenges that current owners are experiencing, necessitating further exploration. The challenges during the operation of solar systems can be grouped into three categories: technical, environmental, and economical. The following sections provide a brief overview of each of these challenges.

Technical challenges

Technical challenges significantly impact the reliability of solar systems, as they often lead to system breakdowns and inefficiencies. These issues can stem from various sources, such as inappropriate sizing of components, the use of second-hand equipment, and installations carried out by unqualified workers. When systems are not properly sized or installed, they may fail to meet performance expectations and experience frequent malfunctions, ultimately reducing their overall reliability and effectiveness. The South African solar market similarly faces issues with substandard products and the high costs of quality equipment.

Homeowners often lack the technical knowledge to differentiate between high and low-quality products, making them susceptible to purchasing inferior components. The drive to keep installation costs low encourages installers to cut corners by using cheaper, substandard products, ultimately leading to reliability issues and reduced system performance. Therefore, the challenges identified by (Dike et al., 2017; Karandikar et al., 2020) are indeed relevant to the South African context, highlighting the need for better consumer education and stricter quality standards in the industry. Another significant technical challenge in South Africa is the lack of knowledge about operating solar equipment. As previously mentioned, batteries require careful management to prevent unexpected failures, while panels, if not adequately maintained, can deteriorate prematurely. These factors contribute to increased maintenance costs and reduced system efficiency over time.

In South Africa, there is a lack of technical expertise especially in the solar home system sector. Technology in this sector is constantly improving, and fewer people are continuously trained which creates a shortage of skills. Installations that are done by people who lack technical expertise will fail or reduce the performance of the PV solar system (Maka, Salem & Mehmood, 2021; Hassan, Algburi, Sameen, Salman & Jaszczur, 2023; Orosz et al., 2024) outlines that there is a lack of technical expertise in SMEs in the PV solar system industry. This could potentially affect consumers who own PV systems in terms of troubleshooting, maintenance, and initial installations. Technical issues pose challenges to consumers who own PV solar systems as described.

Environmental challenges

Environmental challenges also pose significant hurdles to the reliability of solar systems. (Smarte Anekwe, Akpasi, Mkhize, Zhou, Moyo & Gaza, 2024) outlines that solar energy is South Africa's most promising alternative to energy production because it receives more than 2500 hours of sunshine a year with typical solar radiation of 4.5 to 6.5 kWh/m. Studies shown by weather reports have indicated that parts of the western Cape experience terrible weather during winter which results in loss of performance in the solar home systems while Gauteng and other parts are not largely affected.

Hailstorms and floods have become more frequent and severe in South Africa, leading to extensive damage amounting to over R2 billion, which includes significant harm to PV panels used in residential settings. These natural disasters pose a considerable challenge for homeowners relying on solar energy, as they can result in costly repairs or replacements of damaged panels. If the PV panels are not secured tightly on the roof, there is a high chance of them being ripped off by strong winds damaging the equipment. On the other hand, when hailstones strike the panels, they can shatter the glass covering, leading to cracks or complete breakage. This not only compromises the structural integrity of the panel but also exposes the delicate internal components to potential damage. In severe cases, hail can impact the circuitry within the panel, causing electrical shorts or breaking connections, which can disrupt the panel's ability to generate electricity.

Additionally, factors such as shading from nearby structures or vegetation, as well as the geographic location of the system, can further impact its performance. (Maka et al., 2021), argues shading can also be caused by dirt which in turn affects the performance of the systems. In South Africa, strong winds

are a common problem because they carry dust particles and deposit them onto the panels. These environmental factors contribute to the variability of solar energy production and may diminish the reliability of solar systems in certain conditions.

Policies challenges

Another significant challenge in South Africa is the limited availability of programs for buying back electricity from residential PV systems that generate excess power. In areas like Johannesburg, the programs offer low tariffs (Lameez Omarjee, 2023). Furthermore, the process of application, installation, and regulation for these systems is complex and cumbersome. Homeowners must navigate complex hurdles, which can be a major deterrent for those interested in selling their excess energy to the grid. This complexity includes understanding and complying with various regulations and submitting detailed applications. Moreover, the requirement to submit and gain approval for applications before installation adds another layer of difficulty. Many current owners who have already installed PV systems without prior approval find themselves ineligible for these buy-back programs. This lack of retroactive eligibility discourages existing PV system owners from engaging in energy sales, thereby limiting the overall effectiveness of solar energy integration into the grid.

Economic challenges

Economic challenges significantly impact the reliability of solar systems in residential areas of South Africa, particularly during operation. Ongoing maintenance expenses, including repairs and component replacements, pose substantial financial burdens for homeowners relying on solar energy. These costs can strain budgets and limit the accessibility of solar power, potentially hindering the effectiveness and reliability of the systems over time. Additionally, the reliance on imported equipment from other countries contributes to higher operational expenses, exacerbating economic challenges and making it harder for South African households to maintain and sustain their solar installations.

In conclusion, economic, technical, and environmental challenges hinder solar systems' smooth operation in South Africa, necessitating comprehensive policies for sustainability. Addressing high maintenance costs, weather-related issues, and the need for specialised knowledge is essential for effective solar energy deployment.

Reliability assessment

According to (Fara & Craciunescu, 2020), a solar PV system's reliability is defined as the probability that the system can produce energy at its rated capacity for its intended lifespan when used under specified environmental conditions. Conducting reliability analyses of solar PV systems is crucial for ensuring their long-term performance, economic viability, safety, and effective maintenance planning. (Patil, Khalkar, Al-Dahidi, Pimpalkar, Bhandari & Pecht, 2024), outlines that reliability analysis is essential throughout the entire lifecycle of a solar PV system, including product design, manufacturing, installation, and operation. Such an analysis can estimate a system's expected performance over its lifetime and identify potential issues that may affect its long-term reliability. The economic viability of a solar PV system is directly linked to its reliability; a thorough analysis can identify potential sources of failure and estimate maintenance and repair costs over the system's lifetime. This information is vital for calculating the levelized cost of energy and assessing the system's overall economic feasibility.

Factors affect reliability

Reliability in residential solar systems is significantly influenced by a range of technical and environmental challenges. Technical issues such as intermittent power generation due to varying solar irradiance, operational complexities, and equipment maintenance requirements directly impact system reliability. Environmental factors like hailstorms, floods, and environmental degradation further compound these challenges, often causing physical damage to PV panels and reducing overall system efficiency. Before addressing these issues, it is essential to conduct thorough reliability assessments to understand the specific vulnerabilities and operational limitations of each system.

Government solar panel tax program

To encourage investment in clean electricity generation, the South African government has introduced a solar panel tax incentive program, (Godongwana, 2023). This initiative aims to incentivise the adoption of clean energy by providing financial benefits to eligible individuals. Those who pay personal income tax can claim a rebate equivalent to 25% of the cost of new and unused solar photovoltaic panels, with a maximum rebate of R15,000 per person. To qualify, the panels must have a minimum capacity of 275W each and be installed in residential settings. This incentive applies to panels installed between March 1, 2023, and February 29, 2024. By encouraging the adoption of solar energy, this program contributes to a greener and more sustainable future. The challenges faced by current solar energy system owners may act as potential hindrances to the broader adoption of solar energy, as negative experiences can make them less likely to recommend solar PV systems to others.

Research Methodology

This section of the paper will discuss the methodological framework that will guide the research process, research design, data collection methods, and limitations will be included.

Research design

According to (Chenail, 2014) research design is defined as the framework for which the study is used to guide the collection and analysis of the data. This study employed an exploratory qualitative research design. This allows a better understanding of the challenges faced by homeowners with solar PV systems in South Africa. The research adopted an interpretivism philosophy, as outlined by (Myers, 2008), which focuses on comprehending and constructing social phenomena through subjective interpretations rather than objective observations. This approach allowed for an in-depth exploration of how homeowners experience and interpret the challenges of solar systems within their specific contexts. It provides insights into the complex and nuanced personal experiences of solar system owners, (Myers, 2008). The unit analysis of this research will be the owners of solar home systems. A longitudinal time horizontal was used where data was collected over a few weeks or months.

This study employed a qualitative approach, using semi-structured interviews and questionnaires to explore the challenges and reliability of solar systems in residential areas. Semi-structured interviews were used for in-depth discussions, enabling participants to share personal experiences while the researcher explored key topics. These interviews were conducted either in person or via MS Teams, providing valuable qualitative insights into the experiences of solar system owners. Questionnaires were used to increase participation and capture data from individuals who could not participate in interviews. This allowed the study to gather diverse perspectives while staying focused on qualitative data.

Snowball sampling was employed due to the absence of a formal list of solar system owners in South Africa. From literature Pandey and (Pandey & Pandey, 2015), if the population is inaccessible, snowball sampling can be used to enroll participants via other participants since there is no list of owners in South Africa. An invitation to participate in the study was sent via the University of Cape Town school email system, and willing participants were invited to join. Initial participants referred others, resulting in nine interview participants and two individuals who completed questionnaires. A semi-structured interview schedule with key questions linked to the objectives was used for data collection (Myers, 2008; Chenail, 2014). MS Teams interviews were conducted when in-person meetings were not possible, using the video record function.

Ethical considerations were paramount throughout the research process. Participant consent was obtained before data collection, and they were informed about the study objectives and their involvement, ensuring transparency and respect for their autonomy. The study followed the ethical guidelines outlined by (Klopper, 2008; Myers, 2008; Chenail, 2014), ensuring that participants were treated with respect, and their data were handled with the utmost care. The researcher ensured respect, understanding, and empathy, valuing participants' voices. Collected data were protected to avoid any harm to the participants. For effective data analysis, (Myers, 2008), outlines that the researcher needs to be open-minded and attentive to complexities and nuances. The data collected from interviews underwent analysis using Nvivo, a qualitative analysis software used for thematic analysis. Confidentiality was maintained by assigning codes (e.g., R1, R2) to participants, protecting their

identities during the data collection and analysis phases. Data was securely stored and handled to avoid harm or invasion of privacy.

Results

Interviews were conducted with twelve participants to address the research questions. The results of these interviews provided valuable insights and allowed us to identify key themes related to the following inquiries: What challenges do owners of solar systems in residential units in South Africa face? How reliable are solar systems in residential areas of South Africa? What factors affect the reliability of solar systems in residential units in South Africa? The subsequent sections present the detailed findings from these interviews, organised according to the research questions.

RQ1: What challenges do owners of solar systems in residential units in South Africa face?

The research question seeks to explore the negative experiences encountered by these homeowners. The following themes emerged from the study's findings:

Installation and setup challenges

Installation and setup challenges significantly affect the reliability and performance of PV solar systems, often arising from inadequate installation practices. Owners reported that installers did not set up their systems correctly or optimise them for best performance, leading users to resort to trial and error to optimise their systems themselves. One respondent noted, *"It was poorly installed, so the earthing was insufficient and at some point, it started tripping when there was rain."* [R3] Another respondent described their efforts to manage power usage: *"I came up with a plan of switching off and on the battery so that we can save the power and not charge the battery during the day because when you charge the battery during the day, the electricity bill was high. But when I started not charging the battery during the day, I was happy with the change that I introduced."* [R1] Additionally, there were issues with the accessibility of system controls, as one respondent explained, *"The electrical guy who checked my installation also complained that the switches of the inverter were very high, that it wasn't within reach of my control because I think regulations say that you need to be able to quickly switch off something."* [R4] Another respondent outlined that, *"The installation was problematic it took them a good ten days, and they probably came back seven times to get the system working correctly. They had the granny flat neutral on Eskom and everything else. So, every time you switch something on the granny flat, the whole system would trip."* [R9] These insights highlight the need for proper installation practices and user-friendly system setups to ensure the optimal performance and reliability of residential PV solar systems.

Technical and equipment challenges

Technical and equipment challenges encompass problems directly related to the hardware and its performance, which significantly affect the reliability of PV solar systems. Owners reported frequent equipment malfunctions that necessitate replacements, adding to the complexity and cost of maintaining their systems. One respondent described an issue with a new battery: *"When I added a new battery, the battery worked, for like probably a month or two, but then it started becoming faulty, so it wouldn't charge enough. When once you get to 100%, it would just sort of reboot and not get to 100%."* [R4] Another respondent experienced issues with power management, stating, *"Initially when I still had one battery, there was a situation where if I switched on the stove even when it's not load-shedding, the battery would struggle. It would try to push so much from the battery, and then my battery would start beeping with an overvoltage sound and wouldn't charge."* [R4] Additionally, some users faced errors they could not resolve due to a lack of technical expertise, as one user reported, *"At the beginning of this year, the inverter started throwing up another error that we couldn't figure out and we couldn't find a technician to understand what the error was."* Issues with power management were also highlighted, as one respondent noted, *"If we connect too many appliances that draw a lot of current from the system, obviously the interchanging process might not be as smooth."* These challenges illustrate the critical need for reliable equipment and accessible technical support to ensure the effective operation of residential PV solar systems.

Financial and operational challenges

Financial and operational challenges significantly affect the overall cost-effectiveness and functionality of PV solar systems. Many owners report not achieving the expected savings due to their systems' heavy reliance on grid power, which undermines the financial benefits of installing PV systems. Additionally, the process of supplying excess energy back to the grid is often fraught with delays, impacting the financial returns that owners anticipate. One respondent highlighted this issue, stating, *"I don't think you can save money when you have this system because this system needs support; the battery side needs support from Eskom."* [R1] Another respondent mentioned the bureaucratic hurdles involved in grid integration, explaining, *"Getting through the paperwork to supply to the grid is challenging. Cape Town has promised its residents that they will buy electricity from their customers with PV systems. But it seems to be a long process to make it happen now."* [R3] These insights underscore the need for more streamlined processes and greater independence from grid power to enhance the financial viability of residential PV solar systems.

User experience and understanding challenges

This theme addresses the challenges related to the user's interaction with the PV solar system, including monitoring and understanding how to use it effectively. Owners often struggle with monitoring their systems and understanding how to operate them efficiently. One respondent highlighted the initial difficulties in grasping the system's functionality: *"The system challenges that I have encountered was, I think, understanding it at the beginning."* [R1] Another respondent described the inconvenience of monitoring power generation: *"Even if I wanted to know how much power the solar panels were generating, it wasn't so easy because then you'd have to go into the garage where it was installed, and so on."* [R2] These challenges underscore the importance of providing clear guidance and user-friendly interfaces to help owners effectively monitor and manage their PV solar systems.

Support and service challenges

This theme highlights the difficulties owners face in obtaining technical support, which is crucial for maintaining and troubleshooting their PV solar systems. Owners reported challenges in making informed decisions about their systems' efficiency without technical guidance, as one respondent noted: *"There are many little choices that you can now make to tinker with the efficiency of the system, but you can't make those choices without acting in unison with the technical guy."* [R3] Another respondent described the frustration of being unable to reach their installation company: *"The company that installed it stopped returning our calls. We don't know if it went out of business or if we just became persona non grata with them."* [R3] Additionally, another respondent mentioned a lack of support from installers when doing panel cleaning *"Going up on the roof to clean the panels was challenging since the installer does not offer panel-cleaning services"* [R12] These challenges emphasise the need for reliable and accessible technical support to ensure the smooth operation and optimisation of residential PV solar systems.

RQ2: How reliable are solar systems in residential areas of South Africa?

The reliability of solar systems in residential areas of South Africa varies significantly, influenced by a range of factors. Owners were asked to describe the occurrence of unexpected shutdowns, revealing a spectrum of experiences. Frequent shutdowns, occurring more than twice a month, were reported by one household, primarily due to issues such as the inverter not being earthed or installed correctly. Moderate shutdowns, happening once or twice a month, were noted by two households and were often caused by failures in load management, resulting in draining the battery. Rare shutdowns, occurring once in three to six months, were reported by nine households. These findings suggest that while some users experience frequent disruptions due to technical and installation issues, most users encounter only moderate to rare shutdowns, often linked to user-related factors such as improper load management. Overall, the reliability of PV solar systems in South African residential areas is mixed, with both technical and user-related challenges impacting performance.

RQ3: What factors affect the reliability of solar systems in residential units in South Africa?

External and environmental factors

External and environmental factors significantly affect the reliability of PV systems, often beyond the control of the user. Weather conditions play a crucial role, as noted by one respondent who simply stated, *"It's the weather."*[R5] Another respondent highlighted the impact of cloud cover on system performance, explaining, *"The main issue comes and instead of taking us throughout the whole day, maybe to switch off earlier when it's cloudy."*[R2] Additionally one respondent noted *"I have an East-West facing roof and is shaded by the neighbour's trees and in winter there just isn't sunlight on the panels and this affects reliability unless I cut down the neighbour's trees"* [R9] These factors demonstrate how environmental conditions can influence the effectiveness and reliability of solar systems, affecting their overall performance and energy generation.

Technical and equipment issues

Technical and equipment issues encompass problems directly related to the hardware components and their performance, which are critical to the reliability of PV systems. One respondent noted a significant problem with the system's installation, stating, *"The earthing was insufficient and at some point, it started tripping when there was rain"*[R3] Another respondent highlighted the impact of maintenance, noting, *"It looks like my panels might be dirty because we haven't had rain for some time, so I think also that the dust on the solar panels might affect my generation"*[R4] These issues underscore the importance of proper installation and regular maintenance to ensure the optimal performance and reliability of PV systems.

User behavior and usage patterns

User behavior and usage patterns significantly affect the reliability of PV systems. One respondent highlighted the impact of user habits on system performance, stating, *"If we forget to switch off the big appliances or to take them off the solar system, then obviously the battery won't be able to sustain us for the whole night."*[R2] Another respondent described difficulties in monitoring system performance, noting, *"If I wanted to know how much power the solar panels were generating, it wasn't so easy because then you'd have to go into the garage where it was installed."*[R3] These observations illustrate how user practices and the accessibility of system information can influence the overall reliability and effectiveness of solar systems.

Support and service

Support and service are crucial for maintaining the reliability of PV systems, emphasising the importance of accessible and effective technical assistance. One respondent underscored this need by stating, *"The reliability depended on having readily available technical assistance."*[R3] This highlights the critical role that prompt and effective support plays in ensuring the ongoing functionality and performance of solar systems.

System dependence and integration

System dependence and integration reflect how reliance on external power sources and interaction with other systems affect the reliability of PV systems. One respondent noted, *"I think what affects the reliability of the solar system, on hybrids, is to have electricity to charge your battery. I think if your battery is charging 24/7 from your electricity, your solar will be reliable because you won't get these hiccups that I mentioned."*[R1] This highlights the impact of external power sources on the overall performance and reliability of solar systems, emphasising the importance of consistent integration with additional power supplies.

Discussion

The challenges related to installation, setup, and technical aspects of solar systems are significantly influenced by inappropriate system sizing, incorrect load estimation, and inadequate installation practices. When systems are not properly sized, they can either become overburdened or underutilised, leading to inefficiencies and frequent malfunctions. Improper earthing, incorrect panel alignment, and other installation errors can lead to system malfunctions and reduced performance. The findings align

with the existing literature, (Tillmans & Schweizer-Ries, 2011; Campana et al., 2016; Narayan, Papakosta, Vega-Garita, Popovic-Gerber, Bauer & Zeman, 2017; Monyei, Adewumi & Jenkins, 2018), indicating that most challenges stem from inappropriate system sizing, incorrect load estimation, and inadequate installation practices. In the South African context, inappropriate sizing may be caused by unskilled workers and companies looking to make a profit. The solar industry in South Africa has been rapidly increasing, with many companies specialising in solar, some of which use unskilled workers. Additionally, stringent quality control measures should be implemented to mitigate issues related to inappropriate system sizing, incorrect load estimation, and inadequate installation practices.

Financial and operational challenges are influenced by inappropriate system sizing, as well as user behavior and understanding of how to use the system effectively. Inappropriately sized systems can lead to higher operational costs and reduced financial returns. For example, systems that rely too heavily on grid power due to inadequate sizing or improper load management may not achieve the expected savings. Some findings indicate that saving is impossible when using such systems, which contradicts the literature, (Fikru, 2019), suggesting that solar systems aid in saving money. Additionally, some users perceive that savings begin when they start exporting electricity to Eskom, which might not be accurate. Fikru (2019) indicates that there is a need for more vigilant use of electricity to save.

Support and service challenges are influenced by companies engaging in bait-and-switch tactics for profit and the limited availability of experts. These findings contribute to the gap in the literature, (Azimoh, Klintenberg, Wallin & Karlsson, 2015a; Kizilcec & Parikh, 2020), within the South African context. Companies need to be accredited to install solar systems and provide services. Consumers need protection from fraudulent companies and should be educated on how to find accredited suppliers.

The study indicated that the system's reliability is influenced by several factors, such as component quality, system design, weather, and availability of technical assistance. The study found that these systems are reliable, with households experiencing rare, unexpected shutdowns. This aligns with previous studies, (Azimoh, Klintenberg, Wallin & Karlsson, 2015b; Mousavi Ajarostaghi & Mousavi, 2022; Mulaudzi et al., 2022), which suggests that a properly sized system, vigilant user behavior, and high-quality equipment positively influence the reliability of the system. External and environmental factors, such as weather conditions, play a crucial role in the reliability of PV systems. Cloud cover and rainfall can impact energy generation and system performance. Additionally, technical and equipment issues, such as insufficient earthing and dirty panels, further influence system reliability. These findings underscore the importance of both environmental conditions and proper maintenance in ensuring the optimal performance of PV systems. Current literature supports the notion that weather conditions significantly impact solar energy production, aligning with the observed findings.

User behavior, support, and service are also critical to the reliability of PV systems. Users' habits, such as failing to switch off heavy appliances, can deplete battery reserves, leading to performance issues. Additionally, difficulties in monitoring system performance due to inconvenient access can affect effective management. Effective technical support is essential for maintaining system reliability. These observations align with the existing literature, (Azimoh et al., 2015b; Bisaga & Parikh, 2018), which underscores the importance of user behavior and support services in maintaining system performance. However, the specific challenges related to user habits and support services in the South African context may require further exploration to understand their impact on reliability more fully.

Conclusions

The study highlights several critical factors influencing the reliability of residential solar systems in South Africa, including component quality, system design, weather conditions, and availability of technical support. The findings indicate that inappropriate system sizing, incorrect load estimation, and inadequate installation practices are significant challenges that compromise system reliability. These issues are often exacerbated by unskilled workers and profit-driven companies, underscoring the need for stringent quality control measures and proper accreditation of installation companies. Financial and operational challenges also emerge due to inappropriate sizing and user behaviour. Systems that rely heavily on grid power due to inadequate sizing do not achieve the expected savings, contradicting literature that suggests solar systems can aid in saving money. Moreover, the perception that savings start only when exporting electricity to Eskom highlights the need for more vigilant electricity use. Support and service challenges are compounded by companies engaging in fraudulent practices and

the limited availability of experts. This highlights the necessity for consumer education and protection to ensure they can identify accredited suppliers.

Recommendations

Based on the research findings, recommendations for improving residential solar systems in South Africa include enhancing maintenance support, increasing user education, and strengthening policy support. Additionally, fostering technological innovations and community engagement can address current challenges effectively.

For future research, a quantitative approach could focus on conducting longitudinal studies to evaluate the residential solar systems' long-term performance and reliability. Additionally, studying the skill base of solar installation companies can highlight areas for improvement in service quality and training. Technical support models and integration with smart grid technology studies are essential to enhance solar PV system reliability.

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An Exploration of Challenges Affecting Women-Owned Professional Consulting Firms in the South African Built Environment

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Abstract

Women in the built environment are underrepresented as professionals, senior leaders and entrepreneurs. There is plentiful research on challenges encountered by women contractors in the construction industry, however there is minimal research on challenges and constraints encountered by women professionals owning businesses in the built environment sector. This study examined the challenges affecting women-owned professional consulting firms and recommended strategies to support and improve the number of female-owned enterprises in the South African built environment sector. Data was collected from twenty-five purposively selected women owning professional consulting firms using semi-structured interviews. Thematic analysis and Microsoft Excel were utilised to analyse the data. This research showed that women-owned professional consulting firms encounter multiple challenges and barriers, although they are all intensified. The leading barriers are the lack of effective legislation and policy to enforce gender-inclusive procurement. Other challenges include limited access to start-up capital, payment delays, limited access to infrastructure projects, restricted access to the market, and lack of business training, coaching, and mentorship. The study recommends that existing legislation be reviewed and amended to advance the economic empowerment of women-owned businesses operating in the built environment. In addition, it is crucial for the CBE, in partnership with the private sector, the Construction Industry Development Board and the Department of Small Businesses and Development, to develop an integrated strategy to support the diversification of women-owned businesses in the built environment. This research paper holds particular significance for policymakers, industry professionals, and stakeholders committed to advancing sustainability within the built environment industry.

Keywords: Professional, Consulting, Firms, Women, Entrepreneurs.

Introduction

The South African built environment encompasses of various professions, ranging from architecture, construction management, engineering, quantity surveying, property evaluation, landscape architecture, to urban planning, geomatics and environmental management and is reliant on professional skills for the planning, design, delivery, and maintenance of infrastructure (Ramabodu and Nena, 2024:1; Watermeyer and Phillips, 2020:14). The sector is a crucial sector for the country's economy and charged with jobs creation and galvanising investment, however it is experiencing a shortage of professional skills due to an ageing workforce, low rate of entry of graduates, and high attrition (Lawless, 2017; Amrop SA, 2012; Akinshipe, Aigbavboa, Maake, and Thwala, 2019; Thwala, 2022:6).

The built environment is a male dominated sector. evidence shows that women in the built environment are underrepresented as women-owned enterprises and in professional and leadership roles (Aneka, Derera and Bomani, 2017:35; Council for the Built Environment, 2023). For instance, women account for more than 50% of the South African population; however, the statistics indicate that only 13% of professionals registered with the Councils for the Built Environment Professions (CBEP) by the end of 2020/21 financial year were women, compared to 87% of males (Council for the Built Environment, 2022). Moreover, 2022 the cidb transformation barometer reported that, only 30% contracting enterprises are women owned businesses in the South African construction industry (cidb, 2023).

A review of scholarship reveals, there is plenteous research on women contractors in the South African construction industry (Bomani and Derera, 2020; Charuma, Nyoni and Kapepa, 2021; Haupt, and Fester, 2012; Haupt, and Ndimande, 2019; Sospeter, 2017). For instance, Aneke, Derera and Bomani (2017) assessed the challenges faced by women entrepreneurs in the South African construction industry. This study highlighted that the construction sector is male dominated and women are not accepted as equals in the industry. Aneke, Derera, Bomani and Ganiyu (2021) examined the motivational factors and characteristics of women entrepreneurs in the construction industry in South Africa. Their study found that the need to abolish patriarchy, the need for financial independence, the need for empowerment and socio-economic development are major motivators for women entrepreneurs to establish enterprises. Although the scholarship has identified multiple challenges factors affecting women entrepreneurs these studies are limited to women contractors operating in the construction industry (Anuar, Abas, Ibrahim and Hamzah, 2017; Tlapanana and Mngeni, 2021).

There is minimal research on challenges faced by women entrepreneurs registered as professionals operating in the South African built environment sector (Council for Built Environment, 2023; Sangweni and Ozumba, 2023). There has been a growing concern about low gender transformation in the South African built environment professions and the industry has been slow to place diversity, equity and inclusion at the forefront (Haupt and Ndimande, 2019). Therefore, research on female entrepreneurs in the built environment is crucial as it will assist professional bodies to build an empirical basis to develop programmes to support women in the built environment professions and inform research on this research area. This study seeks to address this gap by examining the challenges affecting women professionals owning professional consulting firms and to recommend strategies to be adopted to support and improve the number of female owned enterprises in the South African built environment sector. This study provides a unique contribution to the scholarship on women entrepreneurs operating in male dominated industries in South Africa.

Literature Review

Entrepreneurship is crucial as it stimulates socio-economic development, job creation and reduces unemployment and emigration (Al-Sadi, Belwal and Al-Badi, 2011). Entrepreneurship enables women to attain their business aspirations while managing family and work balance. A woman entrepreneur is an individual who begins a self-owned business, has business acumen and possesses with great persistence (Schumpeter, 2020). Women owners operating in the construction sector are visionaries, strong willed, confident, goal oriented and results driven. There are numerous factors motivating women owners in the construction industry to establish enterprises these include: desire to empower women, yearning for personal growth and self reliance and the opportunity to contribute towards job creation and socio-economic development in communities (Aneke, Derera, Bomani and Ganiyu, 2021).

Scholarship suggests that even though the representation of women owners has increased, they remain a minority in the construction industry (Aneke, Derera and Bomani, 2017; Haupt and Ndimande, 2019). The scholarship suggests that women business owners are confronted by multiple challenges which contribute to their low representation in the construction industry (Bomani and Derera, 2020; Sospeter, Rwelamila, Nchimbi and Masoud, 2014). These challenges include limited access to capital, lack of comprehensive legislative frameworks for gender responsive procurement, and limited access to business support and poor business management expertise as discussed below.

Limited access to capital

Limited access to capital is one of major challenges hindering women from establishing their own enterprises in substantial numbers (Rosa, 2013). Entry to capital markets has been considered as among the most crucial assets restricted to women. Women business owners are discriminated in capital markets based on their limited experience in business management and equity in business and social and gender norms (Nchimbi and Chijoriga, 2009). In addition, women business owners have lower credit than their male counterparts, and women business owners from previously disadvantaged groups are more unlikely than white women business owners to possess bank credit (Haupt and Ndimande, 2019). A strand of scholarship highlights most women entrepreneurs utilise their personal savings as a source of start-up capital for their business (Derera, Chitakunye and O'Neill, 2014; Rosa, 2013). The limited access to financial resources discourages and limits women business owners from bidding and securing government contracts (Amega and Nyang' au, 2017; Basheka, 2018; Mohamed, 2019).

Lack of comprehensive legislative frameworks for gender responsive procurement

At a global level there is recognition that the inclusion of women business owners in public procurement and supply chain is a critical strategy to advance their economic empowerment and level the playing field (Open Contracting Partnership, 2020). However, currently South African government lacks a concise and mandatory legislative framework to guide public officials on gendered procurement (Williams-Elegbe, 2020). In addition, there is a lack of uniform targets for gender-based procurement and a standardised monitoring and evaluation framework to monitor the contracts awarded to women owned businesses (Basheka, 2018).

Lack of business management training, mentors and role models

Business management training provides entrepreneurs with valuable skills and knowledge to traverse the intricacies of establishing and managing a business enterprise. This training equips entrepreneurs to adapt to market changes, accounting, marketing, negotiation, leadership and communication skills and opens the avenues for establish a thriving network of mentors and industry role models (Davies, Moos and van Vuuren, 2023). However, evidence suggests that women entrepreneurs in the construction industry have limited access to business management training is not sufficient and when they do have access to training, they are not offered the full scope of business management training (Haupt and Ndimande, 2019). Mentorships and role models provide entrepreneurs with guidance, direction, support them in carving their career path and assists them to overcome challenges as they arise. However, women in the construction industry have restricted access to mentorship networks and role models. Other challenges that women encounter include difficulties in sourcing clients, lack of infrastructure projects to sustain their businesses, incidents of sexual harassment, poor hygiene and health and safety facilities, lack of confidence, gender discrimination and fear of failure (Aneke and Derera, 2017; Anuar, Abas, Ibrahim and Hamzah, 2017; Chinomona and Maziriri, 2015; Haupt and Ndimande, 2019; Sospeter, 2016).

Research Methodology

This study is exploratory in nature and employed a mixed methods research design involving both quantitative and qualitative research methodologies. Women owning consulting firms in the built environment sector were selected purposively as they are in a position to provide information to address the aim of the study. An invitation and a survey questionnaire requesting for research participants to participate in the study were sent via the professional bodies (architecture, engineering, construction project management, landscape architects, property evaluation and quantity surveying to ease reach of women-owned professional consulting firms. Semi-structured interviews were utilised to solicit qualitative data and survey questionnaires were utilised to collect quantitative data.

Semi-structured interviews were held with women owning consulting firms and registered as professionals with one of the professional bodies within the built environment. Deductive thematic analysis was used to analyse data from the semi-structured interviews. This deductive approach enable analysing data in relation to the themes that emerged through the review of literature and research questions designed for the study. This data was analysed by arranging the data into categories based on themes and constructs, after which the relationship between the constructs was then analysed and later connected in a sequence (Creswell and Creswell, 2018). The qualitative data was managed on ATLAS.ti. The quantitative data that emerged from the survey questionnaire was analysed through Microsoft Excel to produce a table for a statistical representation of research results.

Research Results

The quantitative data derived from the survey questionnaire is presented in section 4.1: Characteristics that define women professionals owning consulting firms (Table 1 and 2). In addition, the qualitative data derived from section 4.2: Challenges facing women owning professional consulting firms. In the qualitative aspect of the study, four themes pertaining to challenges affecting women owned professional consulting firms emerged.

Characteristics that define women professionals owning consulting firms

There are diverse characteristics and attributes that classify women entrepreneurs in different sectors and regions. Characteristics of women business owners are mostly determined by socio-demographic variables and attributes (Wagner and Sternberg, 2004). From the personal information presented in table one, 48% of the participants are African and 24% are white, 20% are Indian and 8% are coloured. Of the sampled women business owners, 56% are between the ages of 30-39 years, 36% between the ages 40-49 years, 4% between the ages of 50-59 years and 4% 60 years and above. All the women business owners sampled are managing consulting firms, 72% of them are registered as private companies, 35% are registered as sole proprietorship and 24% are registered as close corporations. The research findings reveal that 47% of consulting firms owned by women have been registered and active for 6-9 years, 24% have been registered and active for 10 years and above, 18% have been registered and active for 1-2 years and 12% have been registered and active for 3-5 years.

Table 1: Demographics of women professionals owning consulting firms

Participants demographics		n	%		
Race	African	12	48%		
	White	6	24%		
	Indian	5	20%		
	Coloured	2	8%		
Age	30-39 years	14	56%		
	40-49 years	9	36%		
	50-59 years	1	4%		
	60 years and above	1	4%		
Type of company	Closed corporation	1	4%		
	Private Company (Pty) Ltd	18	72%		
	Sole proprietorship	6	24%		
Number of years company has been. (a) registered & (b) active	1-2 years	(a) 1	(b) 1	(a) 4%	(b) 4%
	3-5 years	4	4	16%	16%
	6-9 years	13	13	52%	52%
	10 years and above	7	7	28%	28%
Does the company have employees?	No	20	80%		
	Yes	5	20%		
Company turnover	R1-R335000	4	16%		
	R335001- R500 000	2	8%		
	R500001-R750000	8	32%		
	R750001 and above	11	44%		
TOTAL		25	100%		

Table two shows the professions that women business owners are registered with. For instance, 28% of women business owners are from the architectural profession, 17% are from the engineering profession, 17% are from the town planning profession, 17% are from the landscape architecture profession, 10% are from the quantity surveying profession and 10% are from the project and construction management profession.

Table 2: The Professions of women owning professional consulting firms

Profession	Percentage (%)
Architecture	28%
Engineering	17%
Landscape Architecture	18%
Town Planning	17%
Quantity Surveying	10%
Project and Construction Management	10%

Challenges facing women owning professional consulting firms

Limited access to start-up capital

Adequate access to funding or finance is critical to assist the entrepreneur in purchasing fixed assets and to provide working capital until the business achieves a break-even point. Previous studies identified limited access to capital as one of the major obstacles for women entrepreneurs (Chinomona and Maziriri, 2015; Haupt and Ndimande, 2019). The results of this study corroborate with previous studies. The study found that most women owning professional consulting firms faced challenges to accessing funding during the start-up phase of their businesses. To illustrate the challenges that women owned enterprises in the built environment encounter with regards to access to start-up funding. The following statements by the participants are highlighted to support these findings:

Participant A1 responded:

"This biggest start-up challenge I faced was the lack of funding to start my company. I had to utilise my savings, and it was not adequate for the day-to-day expenses of the business. This affected the operations of my business." Taking the quote into consideration, the participant is a black woman who had to use her personal investment to start her company. Although she used personal savings to establish her business, the money she raised was not sufficient to operate her business. The findings of this study are concert with previous literature that most women entrepreneurs utilise their personal savings as a source of start-up capital for their business (Derera, Chitakunye and O'Neill, 2014; Rosa, 2013). Rouse and Jayawarna (2006) point out that personal savings comprise of capital accumulated from previous employment, family savings and financial contributions from family and friends.

Access to finance remains a persistent obstacle for women entrepreneurs (Aneke, Derera, and Bomani, 2017; Sospeter, 2016). Yet capital is crucial for an entrepreneur to launch a business successfully as limited access to capital hinders business growth (Obayumi, 2010). The equipment and machinery are expensive in the construction industry and in some instances, women outsource components of the jobs to other companies which unfavorably affect the return on investment (Aneke, Derera an Bomani, 2017). In many instances personal savings are not an adequate source of start-up capital (Derera, Chitakunye and O'Neill, 2014). This study found that 70% of the women owning professional consulting firms used their personal savings accumulated from previous employment for the start-up phase of their business, while 15% utilised credit from banks (loan and credit cards) as source of start-up capital and the remaining 15% of women obtained capital from family and friends.

Lack of gender responsive procurement policies and systems to implement gender responsive procurement

In the present study most, participants highlighted that women owning professional consulting firms encounter multiple impediments from effective participation in public procurement due to the lack of expression of gendered procurement in economic and legal frameworks, policies, and processes. These research findings corroborate with previous literature that multiple countries lack the mechanisms to mainstream women owned businesses in their public procurement frameworks, policies, and systems (Open Contracting, 2021; Williams-Elegbe, 2021). In the present study women owning professional consulting firm reported that their enterprises are small, revenue, expertise, experience, and the of number of employees employed.

Thus, women owning professional consulting firms highlighted that they are unable to participate in public procurement processes because their businesses lack the technical and managerial experience required to bid and secure government tenders. Consequently, the public procurement system favours larger and more experienced businesses which are often owned by males. Women owned businesses in this study felt they are not on an equal footing to penetrate the market and acquire critical assets required to sustain businesses. The following statements by the research participants support these findings:

Participant B00 responded:

"The fact that there is no policy guiding targeted procurement is a challenge as women owned enterprises are not catered for. As a result, this marganalises women from public tenders."

Participant B01 responded:

"Currently there is no policy or regulation guiding the public sector on how to implement gender responsive procurement, as a result the president's pronouncement of 10% for women owned business is not being implemented. As women owned businesses, we are excluded from participating fully in public procurement."

Barriers in penetrating the market and lack of cashflow

The study also found that penetrating the market is a major challenge encountered by women owning professional consulting firms. Most women business owning professional consulting firms reported that clients require bidders to possess substantial technical experience. Consequently, women owning professional consulting firms revealed that this requirement hinders the ability to obtain work. The following statements by the participants support these findings. Participant C01 responded: *"Public bids require substantial company experience. This system is exclusionary as it is public knowledge that male entrepreneurs have been in business longer than us and they have more company experience than females. As a result, we don't apply for tenders because we do not meet the minimum requirements."* The following statements by the participants support these findings. Participant C02 responded: *"Our companies are specialised, and we also have smaller contractual expertise. We are made to compete with big companies. This practice is exclusionary. There should be public infrastructure projects that are ring fenced for women owned businesses."*

Women owning professional consulting firms also highlighted that they are struggling to get work from clients, and this affected their cashflow. These findings corroborate with the findings of a previous scholarship whereby it was revealed that women entrepreneurs in the construction industry in South Africa encountered challenges in terms of sourcing clients and this is critical for the sustainability of the business (Aneke and Derera, 2017). In a similar vein, a study conducted on challenges facing women entrepreneurs in the construction industry in Tanzania highlighted that women entrepreneur struggled to obtain infrastructure projects to maintain their businesses (Sospeter, 2016). This is the reality. However, the continuous flow of capital in a business is crucial for its sustainability and growth.

A positive cash flow assists businesses to maintain positive financial relationships with both clients and suppliers (Smith, 2021). The following statements by the participants support these findings: Participant C3 responded: *"I think the biggest challenge, like I said, was being able to make sure that I had infrastructure projects so that I can have cashflow. We also battled to get projects off the ground of a larger scale because of the lack of cash flow."* The following statements by the participants support these findings: Participant C4 responded: *"Working capital is an issue because if you do not have income, then how do you keep going? So, the business experiences cash flow problems. It really took about a year for me to match what I had been earning before in a firm because of the lack of cashflow."* The following statements by the participants support these findings: Participant C5 responded: *"As women business owners we are really struggling to get projects because public tenders require company experience, we do not possess, and the lack of projects is affecting our cashflow."*

Incidents of sexual harassment and health and safety concerns

The built environment sector is hostile in that it exposes one to several work-related operational and environmental risks, mostly linked to poor physical health such as cardiovascular and muscular disorders and respiratory illness (Akinlolu, Olalusi and Haupt, 2020). Scholarship points out that sexual harassment is one of the major barriers and challenges faced by women in the construction industry in South Africa and Malaysia (Anuar, Abas, Ibrahim and Hamzah, 2017; Smallwood and Agherdien, 2008). The equipment, tools, and personal protective equipment (PPE) for work is designed to fit male bodies leaving women with the challenge of finding suitable PPE with the right fit (Rani, 2018).

The present study found that women experienced gender discrimination, were exposed to hazards on construction and work attire did not fit women. Participant D1 responded: *"As a woman I experience health and safety issues, as it is not safe for a woman to go alone on vacant land to take pictures. Some construction sites have serious hazards. Anything can happen. And some of these clients are based in townships."* Participant D2 responded: *"I have experienced sexual harassment in the workplace where a male in a senior management position was making inappropriate remarks about my body and dress sense. As a matured woman I addressed the issue head on."* Participant D3 responded: *"I struggle finding suitable work attire that fit female bodies as the work attire is manufactured for male bodies."*

The findings of this study are consistent with previous literature highlighting that women continue to face sexual harassment, bullying, uncomfortable work tools and limited hygiene/sanitary facilities which expose women to unsafe working conditions and these factors restrain women from active participation in construction industry (Chinomona and Maziriri, 2015).

Discussion

The intention of this study was to examine challenges faced by women owning professional consulting firms and support required for women's entrepreneurial success in the built environment sector. Being ambitious and agile is essential for entrepreneurs as it effects investors commitment to invest in the business (Barringer and Ireland, 2010). The findings of the current study indicate that most of the women business owners in the built environment are between the ages of 30-39 years. This research finding corroborates with previous literature that most entrepreneurs are young and vibrant, and they fall within the ages of 35 and 45 years (Xavier, Ahmed, Nor and Yusof, 2012). The study found that all women business owners running professional consulting firms. A key feature of the research findings is that most women owned business are newly established businesses. The data shows that 47% of the women-owned businesses sampled in this study have been operating for 6-9 years, 24% of the businesses that have been operating for 10 years and above, 18% of businesses have been operating for 1-2 years and 12% have been operating for 3-5 years.

This study reveals that women professionals owning professional consulting firms share certain characteristics and attributes. All women owning professionals sampled in this study have built environment qualifications, had worked in the built environment sector for eight years and above prior to venturing into entrepreneurship and were all registered with either the architecture, engineering, landscape architecture, quantity surveying and project and construction management and town planning professions. Additionally, this study highlights that woman owning professional consulting firms possessed multiple entrepreneurial skills and attributes such as ambition, high levels of energy, self-belief in their technical and management skills, stakeholder relations skills and perseverance.

Women owning professional consulting in the built environment sector encounter multiple challenges though with different intensities. The leading challenges among these are the lack of mechanisms (policy and legislation) to implement gender inclusive procurement, lack of access to start-up capital, difficulties in sourcing clients, payment delays which resulted in the lack of cash flow. Most women owning professional consulting firms also reported that they encounter high levels of sexual harassment, gender discrimination, health, and safety hazards on construction sites. Furthermore, women businesses lack the experience and expertise to compete with experienced enterprises owned by their male counterparts. As a result, women owning professional consulting firms struggle to penetrate the market. Women business owning professional consulting firms reported that they require structured business training and business mentorship and access to funding to sustain their businesses.

Conclusion

The study explored a previously neglected research area on challenges facing women owned professional consulting firms and to recommend strategies to be adopted to support and improve the number of female owned enterprises in the South African built environment sector. Women owned businesses are becoming an important contributor to economic development and their role becomes more critical in improving the financial situation of developing countries. Therefore, this study established major challenges faced by women owning professional consulting firms include the lack of access to start-up capital, payment delays, restricted access to the market and the lack of business training and mentorship. In addition, other challenges incl lack of gender responsive procurement policies and systems to implement gender responsive procurement, sexual harassment and health and safety concerns and limited access to infrastructure projects which results in the lack of cash flow in their businesses.

Recommendations

In recent years, the Council for the Built Environment (CBE) has recognised the need for a more robust support system to address the persistent challenges faced by women business owners in the sector. In collaboration with professional bodies, voluntary associations, and key partners, the CBE is now

considering the development of specialised business support programs - most notably, incubators to provide targeted assistance to women entrepreneurs.

These incubators are envisioned as dynamic spaces where women business owners can receive the technical and financial resources necessary to build sustainable and successful businesses. The programs would be designed with a multifaceted approach, addressing critical areas essential for long-term growth and empowerment.

Technical exposure

One of the core components of the incubator program would be providing women entrepreneurs with increased access to technical knowledge and industry-specific training. This exposure would ensure that participants stay abreast of cutting-edge technologies, industry trends, and best practices in areas such as construction management, design innovation, and infrastructure development. By equipping women with advanced technical skills, the program would help level the playing field, allowing them to compete effectively in a male-dominated industry.

Financial strategy development and business acumen

Another key focus of the incubators would be developing strong financial strategies and fostering business acumen among participants. Women business owners often face greater challenges in accessing capital and managing the financial aspects of their companies. The program would provide in-depth workshops on financial planning, securing funding, and managing business finances, helping participants develop sustainable strategies that foster long-term growth. With access to financial experts, participants would gain the skills needed to create budgets, analyse financial data, and make strategic decisions to scale their businesses.

Mentorship and coaching

A critical pillar of the incubator programs would be access to mentorship and coaching with industry leaders and business experts. By pairing participants with experienced mentors, the program would offer women business owners personalised guidance and support as they navigate the challenges of entrepreneurship. This mentorship would not only provide valuable insights into managing business operations but would also help women build lasting networks, connecting them with industry contacts and business opportunities.

Building a supportive ecosystem

At the heart of this initiative is the desire to create an inclusive and supportive ecosystem where women-owned businesses can thrive. The partnership between the CBE, professional bodies, voluntary associations, and relevant stakeholders would ensure that women entrepreneurs have access to the resources, knowledge, and networks they need to succeed. The incubators would serve as launchpads for innovation and growth, helping women overcome structural barriers and make their mark in the built environment.

By offering comprehensive technical, financial, and leadership training within a nurturing environment, these incubators could revolutionise the way women participate in the built environment sector. They represent a critical step toward creating a more equitable industry - one where women are empowered to lead and succeed on their terms.

The Council for the Built Environment (CBE), in collaboration with professional bodies, voluntary associations, and relevant partners, is considering the creation of a robust, supportive network designed to connect women business owners across various disciplines within the built environment sector. This network would serve as a comprehensive platform for knowledge sharing, professional development, and advocacy, with a vision of fostering growth and opportunity for women entrepreneurs.

One-stop resource hub

The network would also serve as a one-stop resource hub where women-owned businesses could easily access critical information related to enterprise development, business management, funding

opportunities, and career advancement. Often, one of the key challenges for women entrepreneurs is navigating the complex array of resources needed to grow their businesses. This hub would streamline that process by offering easy access to a wealth of information in one central location. Whether seeking guidance on securing business funding, developing a marketing strategy, or accessing training programs, women could turn to the network for all their needs.

Advocacy and lobbying for increased participation in procurement

Beyond its role as a resource center, the network would also play a significant role in advocacy and lobbying, particularly in relation to government procurement. Currently, women-owned businesses often face significant barriers when it comes to accessing government contracts. The network would advocate for greater representation and participation of women in the procurement space, working with government agencies to develop policies that prioritise inclusivity and promote equitable access to business opportunities.

By leveraging its collective strength, the network would lobby for policies that ensure more women-owned businesses are included in major government infrastructure projects, urban development contracts, and other large-scale initiatives. This advocacy could transform the procurement landscape, opening up new opportunities for women business owners to contribute to the country's development and economic growth.

A transformational initiative for women entrepreneurs

The creation of this supportive network represents a bold and forward-thinking initiative that could reshape the built environment sector. By fostering connections, promoting knowledge sharing, and advocating for increased participation, the network would empower women business owners to overcome traditional barriers and thrive in the industry. More than just a resource hub, it would be a platform for change—driving progress toward a more inclusive and equitable future where women-owned businesses play a central role in shaping the built environment.

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Analysing the Obstacles to the Adoption of Green Building Technologies: a Quantitative Analysis

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Abstract

Green building technologies (GBTs) play a critical role in reducing energy consumption, preserving resources, and improving the environmental state of buildings. This paper aims to evaluate the obstacles preventing GBTs from being widely used. This study adopted a quantitative research technique. The data was collected using a closed-ended survey questionnaire among construction professionals in the Free State Province of South Africa. The study discovered that the main obstacles preventing the adoption of GBTs are those linked to economic, technological, knowledge-based, political, and time-related. Furthermore, the GBT adoption strategy was developed with the recognition of the obstacles to GBT adoption in mind. The GBT adoption strategy aims to lay forth a plan for GBT adoption in the construction industry. The survey's use imposes several limitations on the study. For example, the survey results only apply to one of the nine provinces that make up South Africa. Also, the proposed GBT adoption strategy has not been tested on an actual construction project. This study offers valuable perspectives for formulating the GBT adoption strategy for improving the adoption of GBTs in the South African construction companies' efforts towards fostering sustainability.

Keywords: Construction Industry, Green Building Technology, Sustainability.

Introduction

The construction industry is one of the primary industries accountable for massive energy consumption and greenhouse gas (GHG) emissions (Kong & He, 2021). For example, reports indicate that in 2020, the construction industry accounted for 37% of global carbon emissions and used about 36% of the world's end-use energy (Hu et al., 2023). The situation is much more serious in South Africa, where the construction industry accounts for around 7% (34 Mt CO₂e) of the nation's direct emissions (Chaumontet et al., 2023). The authors also noted that South Africa, which is expected to be one of the most severely affected countries in the region by climate change, suffers from extreme housing inequality, with a shortage of about 2.1 million homes and unequal access to public infrastructure, such as water and sanitation.

Achieving sustainability in South Africa would benefit from addressing the consumption of energy and greenhouse gas emissions. As a result, green buildings (GBs) could be a way to reduce greenhouse gas emissions and energy use in the building industry (Hu et al., 2023). Green buildings (GBs) can mitigate negative effects and improve the environment and climate at the same time by means of their construction, operation, or design. Moreover, GBs cover the full building life cycle, employing resource- and environmentally-conscious methods at every stage, from planning and designing to building, operating, maintaining, repairing, and dismantling a building (Kong & He, 2021).

Green building technologies (GBTs) are being used by the construction industry to reduce the negative effects that building energy use and GHG emissions have on the environment, society, and economy (Chen & Tang, 2023). To encourage the integration of GBTs within the construction industry, professionals must specify the implementation difficulties in greater detail. The construction industry has improved the promotion of sustainability in its operations and reduced these negative consequences by utilising a variety of GB technologies (Lee et al., 2023).

GBTs, a relatively new and distinctive building technology, have surpassed traditional building technologies and become an important strategic element (Zhang et al., 2023). In addition, GBTs play a critical role in reducing energy consumption, preserving resources, and improving the environmental state of buildings. Buildings have been demonstrated to emit enormous amounts of GHG emissions and demand large amounts of energy. Furthermore, it is argued that the majority of South African

construction firms continue to use traditional building techniques, even in the face of the introduction of Green Building Technologies (GBTs), which are meant to promote sustainability (Green Building Council South Africa, 2021). To address this reported problem, the following research objectives were investigated in this study:

- To evaluate the obstacles preventing the widespread adoption of green building technologies.
- To develop a strategy for adopting green building technologies to improve their application in the construction industry.

Literature Review

According to Zhao et al., (2024), the process of GBTs is complex and entails the application of green concepts, developing green technologies, and commercialising green products. The authors went on to further define the three key domains of GBTs as the influence of the external environment, the interaction of internal innovation entities, and the engagement of numerous stakeholders. In addition, Opoko et al. (2022) assert that GBTs are enhancements made to building layout and design to make them more sustainable. The authors continued, saying that although GB is conceivable in constructing, GBTs can be used. Although the construction industry supports GBTs as a way to address sustainability issues, there are still several obstacles preventing their widespread use (Chan et al., 2018).

Using a set of modern approaches known as GBTs, buildings are planned with the environment in mind (Kong & He, 2021). The author further stated that the whole building lifecycle, from design and construction to operation and maintenance, refurbishment, and demolition, is covered by the application of these contemporary methodologies. GBTs have several benefits, including more energy-efficient buildings and lower construction and operating expenses (Carlander & Thollander, 2023). According to Fitriani & Ajayi (2022), the objective of GBTs is to reduce the harmful consequences that buildings have on the environment, such as resource depletion and carbon dioxide emissions.

GBT has grown in popularity during the last several decades. However, to implement GBTs, developing countries typically need to provide demand, cost, governance, and comprehension support (Nikyema & Blouin, 2022). Customers and clients will also have the biggest influence on the implementation of GBTs, as the construction industry won't be forced to follow GBT standards unless they are ready to select sustainability and energy efficiency (Guribie et al., 2022). The authors continue by saying that as consumers are what drive GBTs in the market, it is impossible to overestimate their significance in this context. GBTs integrate ecologically and resource-conscious design, machinery, materials, and building practices over their whole life cycle (Juan & Lee, 2022). Other examples of GBTs include energy-efficient HVAC systems, natural ventilation, water capture and grey water treatment, solar energy and shading, green roofs, fixtures and windows that use less energy, and natural ventilation (Nikyema & Blouin, 2022). Table 1 summarises the obstacles preventing the adoption of GBTs. There are six primary obstacles, each of which has a sub-obstacle.

Table 1: Obstacles preventing the adoption of GBTs

No	Factors	Sub-factors	Code	Sources
1	Economic obstacles	High cost of GB materials	EC1	(Lee et al., 2020; Yee et al., 2023; Berawi et al., 2020; Kumar & Agarwal, 2022; Roslee et al., 2022; Chen & Tang, 2023; Zhang et al., 2023; Nugrad, 2021; Kumar & Agarwal, 2022; Roslee et al., 2022; Chen & Tang, 2023)
		Lack of market opportunities	EC 2	
		Few material suppliers	EC3	
		Lack of financial supports for GBTs	EC4	
2	Technological obstacles	Lack of database relating to GB materials	TO1	(Juan & Lee, 2022; Assylbekov et al., 2021; Lee et al., 2020; Yee et al., 2023; Berawi et al., 2020; Kumar & Agarwal, 2022; Komurlu et al., 2024)
		Few GB experts	TO2	
		Poor adoption of GBTs	TO3	
3	Knowledge-based obstacles	Poor public awareness of GB	KO1	(Jaradat et al., 2024; Wang, Chen, & Nah, 2024; Kumar & Agarwal, 2022)
		Lack of knowledge of GB	KO2	

		Lack of professional knowledge	KO3	
4	Political obstacles	Poor adoption of GB policies and regulation	PO1	(Karamoozian & Zhang, 2023; Yee et al., 2023)
		Lack of enforcement of law	PO2	
5	Duration obstacles	Long project duration	DO1	(Lee et al., 2020; Yee et al., 2023)

Research Methodology

The research design chosen for the study was quantitative, as advised by Creswell and Clark (2018). Using the quantitative research technique, the researcher examined the following objectives:

- To evaluate the obstacles preventing the widespread adoption of green building technologies.
- To develop a strategy for adopting green building technologies to improve their application in the construction industry.

As a result, the data was collected using a closed-ended survey questionnaire among construction professionals in the Free State Province of South Africa. As a result, there were two sub-questions on the survey questionnaires. The survey was designed using the identified aspects of the literature review. In total, thirteen (13) sub-aspects were evaluated in the survey (see Table 1).

The study's target population includes construction professionals, as Table 2 shows. The survey was completed by 52 respondents in total. It was distributed randomly among professionals in the construction industry in the Free State province. As advocated by Creswell and Clark (2018), a simple random sampling technique was used to choose the construction professionals, which included project managers, architects, quantity surveyors, civil engineers, electrical engineers, site agents, site foremans, and artisans. Male respondents make up 71% of the sample, while female respondents make up 29%.

Table 2: Research sample

No	Job titles	Frequency (No)	Percentage (%)
1	Project managers	4	7.69
2	Architects	5	9.62
3	Quantity surveyors	6	11.54
4	Civil engineers	3	5.77
5	Electrical engineers	2	3.85
6	site agents	7	13.46
7	Site foremans	13	25.00
8	Artisans	12	23.07
Total		100	100

For collecting quantitative data, closed-ended survey questions were utilised. In 2024, data was collected between June and July. This resulted in the study's cross-sectional design, which received guidance from Creswell and Clark (2018). In the survey's initial section, the researcher was given information on the respondents' demographic data. The survey's second section used a Likert scale, ranging from 1 to 5, to assess the obstacles to the adoption of GBTs. On the Likert scale, 1 was regarded as minor, 2 as slightly important, 3 as neutral, 4 as considerable, and 5 as highly significant. The quantitative data were subjected to a descriptive statistics analysis using mean scores (MS) and standard deviations (SD). The Statistical Package for Social Science (SPSS) was used to analyse the quantitative data using an MS and SD. Additionally, SPSS was used to test the factor analysis of the thirteen obstacles to the adoption of GBTs.

Research Results

An assessment of the obstacles to the adoption of GBTs

Table 3 shows responses from the 51 survey respondents who answered the questions on the obstacles to the adoption of GBT in South African construction projects. A Likert scale rating between 1 and 5 was used to evaluate the obstacles to the adoption of GBT, as shown in Table 1. The findings of the survey are categorised into five major aspects and thirteen sub-aspects that are regarded to be the obstacles to the adoption of GBTs on construction projects. The overall mean score of the thirteen sub-aspects was above 3.00, indicating that most respondents agreed that the obstacles were contributing factors to the adoption of GBTs. Furthermore, the findings of this study show that the SD is within an acceptable range, suggesting that the respondents' comments varied little from one another. For example, TO3 has the lowest SD at 0.793, whereas EC3 has the highest value at 1.093. Thus, it can be accepted that the adoption of GBTs is influenced by those identified obstacles, which include economic, technological, knowledge-based, political, and time-related obstacles.

Table 3: The obstacles to the adoption of GBTs

No	Aspects	Sub-aspects	MS	SD	Ranking	Remark
1	Economic obstacles	EC1	3.87	1.010	2	Accepted
		EC2	3.81	1.011	4	Accepted
		EC3	3.54	1.093	11	Accepted
		EC4	3.60	1.072	9	Accepted
2	Technological obstacles	TO1	3.62	0.867	8	Accepted
		TO2	3.56	1.074	10	Accepted
		TO3	3.81	0.793	3	Accepted
3	Knowledge-based obstacles	KO1	3.62	1.087	7	Accepted
		KO2	3.63	0.864	6	Accepted
		KO3	3.67	1.004	5	Accepted
4	Political obstacles	PO1	3.92	1.064	1	Accepted
		PO2	3.50	1.000	12	Accepted
5	Time related obstacles	DO1	3.48	1.075	13	Accepted

Factor analysis of the obstacles to the adoption of GBTs

The thirteen (13) obstacles to adopting GBTs were broken down into more manageable and significant categories using factor analysis. The first step in the analysis was to ascertain whether the relevant variables were appropriate and factorable. As shown in Table 4, the correction matrix for the thirteen sub-aspects yielded satisfactory coefficients ranging from 0.858 to 1.00.

Table 5 also presents the results of the Kaiser Meyer-Olkin (KMO) measure of sample adequacy and Bartlett's test of sphericity for each of the thirteen sub-aspects. The test evaluates the relationship among the thirteen sub-aspects as well. As can be seen, Table 5's KMO value of 0.917 is significant because it is higher than 0.50. Additionally, Table 5 indicates an acceptable significance level of 0.001. The results show a similarity between the two tests, as Table 4 shows the correlation between the identifying matrix and the correction matrix.

Table 4: Correlation matrix

	EC1	EC2	EC3	EC4	TO1	TO2	TO3	KO1	KO2	KO3	PO1	PO2	DO1
EC1	1.000	0.973	0.902	0.909	0.858	0.902	0.873	0.916	0.864	0.922	0.957	0.883	0.891
EC2	0.973	1.000	0.912	0.923	0.854	0.914	0.883	0.931	0.861	0.942	0.953	0.893	0.899
EC3	0.902	0.912	1.000	0.977	0.906	0.942	0.891	0.970	0.898	0.932	0.897	0.951	0.977
EC4	0.909	0.923	0.977	1.000	0.907	0.950	0.899	0.975	0.918	0.950	0.902	0.961	0.955
TO1	0.858	0.854	0.906	0.907	1.000	0.888	0.889	0.880	0.987	0.889	0.839	0.950	0.897
TO2	0.902	0.914	0.942	0.950	0.888	1.000	0.934	0.976	0.900	0.954	0.897	0.940	0.935
TO3	0.873	0.883	0.891	0.899	0.889	0.934	1.000	0.913	0.897	0.929	0.842	0.890	0.892
KO1	0.916	0.931	0.970	0.975	0.880	0.976	0.913	1.000	0.891	0.960	0.906	0.938	0.949
KO2	0.864	0.861	0.898	0.918	0.987	0.900	0.897	0.891	1.000	0.899	0.844	0.942	0.889
KO3	0.922	0.942	0.932	0.950	0.889	0.954	0.929	0.960	0.899	1.000	0.912	0.927	0.929

PO1	0.957	0.953	0.897	0.902	0.839	0.897	0.842	0.906	0.844	0.912	1.000	0.885	0.890
PO2	0.883	0.893	0.951	0.961	0.950	0.940	0.890	0.938	0.942	0.927	0.885	1.000	0.939
DO1	0.891	0.899	0.977	0.955	0.897	0.935	0.892	0.949	0.889	0.929	0.890	0.939	1.000
EC1		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EC2	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EC3	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EC4	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TO1	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TO2	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
TO3	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000
KO1	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000
KO2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
KO3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000
PO1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000
PO2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000
DO1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Table 5: KMO and Bartlett's Test

Parameter	Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.917
Approx. Chi-Square	1617,848
Bartlett's Test of Sphericity	df 78
	Sig. 0.001

Discussions

GBTs are being used by the construction industry to reduce the negative effects that building energy use and GHG emissions have on the environment, society, and economy (Chen & Tang, 2023). It is also reported, underscoring the research problem, that the construction industry is one of the primary industries accountable for massive energy consumption and GHG emissions (Kong & He, 2021). Thus, this study aims to evaluate the obstacles preventing GBTs from being widely used. The researcher identified the five primary barriers in the literature review (Table 2) to achieve this goal. These obstacles include economic, technological, knowledge-based, political, and time-related obstacles. The economic obstacles include the high cost of GB materials (EC1), lack of market opportunities (EC2), few material suppliers (EC3), and lack of financial support for GBT (EC4). The technological obstacles include a lack of databases relating to GB materials (TO1), few GB experts (TO2), and poor adoption of GBT (TO3). Knowledge-based obstacles include poor public awareness of GB (KO1), lack of knowledge of GB (KO2), and lack of professional knowledge (KO3). The political obstacles include poor adoption of GB policies and regulations (PO1) and lack of enforcement of law (PO2). The duration obstacles include long project durations (DO1).

In addition, Table 3 presents the survey results, demonstrating that respondents agree that the obstacles mentioned in Table 2 affect GBT implementation. The results presented in Tables 4 and 6 demonstrate the viability and factorability of the thirteen (13) studied variables. As a result, Figure 1 provides a strategy for establishing GBT adoption. The proposed strategy is developed using the obstacles that were analysed and discovered in this study. There are thirteen aspects in the roadmap that were used for developing this GBT adoption strategy. We put up this strategy to address the obstacles preventing the widespread adoption of GBT. Thus, this would support the construction industry's efforts towards fostering sustainability.

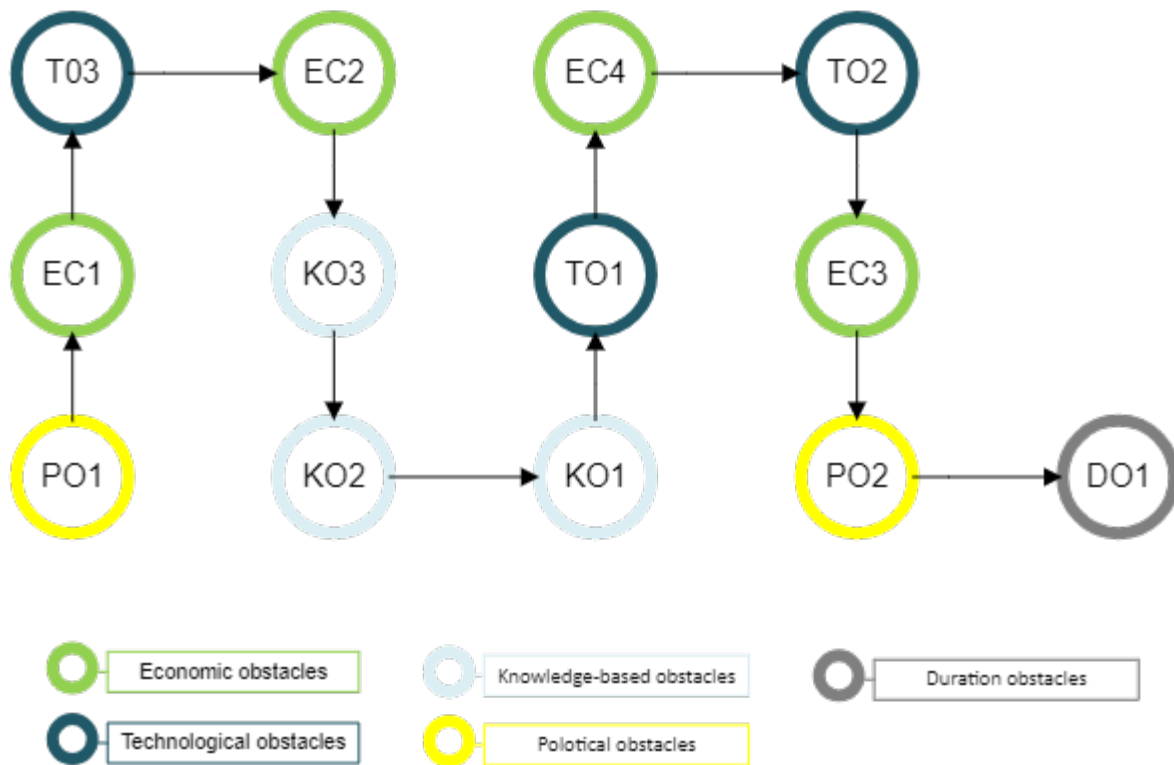


Figure 1: The GBT adoption strategy

Conclusion

The construction industry is in support of using GBT to address sustainability concerns, but there are several obstacles to overcome. An in-depth analysis of the obstacles inhibiting the adoption of GBT is necessary. To address this problem a survey of 52 professionals in the construction industry was undertaken to examine the five primary obstacles to GBT adoption that were identified in the literature review. The study discovered that the main obstacles preventing the adoption of GBTs are those linked to economic, technological, knowledge-based, political, and time-related. These primary obstacles consisted of thirteen (13) sub-obstacles: EC1, EC2, EC3, EC4, TO1, TO2, TO3, KO1, KO2, KO3, PO1, PO2, and DO1. The results shown in Table 3 indicate that participants agreed that these thirteen (13) sub-obstacles had a role in the adoption of GBTs. In addition, the results presented in Tables 4 and 6 demonstrate the viability and factorability of the thirteen (13) sub-obstacles.

Furthermore, the development of the GBT adoption strategy took into account the obstacles to its adoption. The thirteen steps of the GBT adoption strategy are shown in Figure 3. It is important to understand that the GBT adoption strategy serves as a model for GBT adoption in the construction industry. Another objective of the GBT adoption approach is to lay out an adoption plan. The use of the survey imposes several limitations on the study. For example, the results of the survey only apply to one of the nine provinces that make up South Africa. The study's response rate is extremely poor as a result. Future research projects need to use an alternate research approach to collect data. For example, an action study design is recommended to investigate the proposed GBT adoption strategy on actual construction projects in South Africa.

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Analysis of the Impact That Evolving Quantity Surveying Client Services Have on Mining Capital Projects

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Abstract

The evolution of Quantity Surveying (QS) client services within the context of Mining Capital Projects carries significant implications for project outcomes, resource allocation, and industry dynamics. This paper comprehensively analyses the ramifications of these evolving services, focusing on their impact on the need for Quantity Surveyors through various project phases. The research illuminates the nuanced interplay between evolving QS client services and the intricate fabric of Mining Capital Projects. The study uncovers insights that transcend conventional paradigms by scrutinising key metrics such as cost efficiency, job creation potential, and project flow optimisation. Data collection involved engaging with stakeholders across the spectrum of Mining Capital Projects, including Quantity Surveyors, Engineers, and Client personnel. Through interviews and qualitative analysis, the research captured diverse perspectives and extracted beliefs regarding the role and impact of QS services. The significance of this research extends beyond the confines of the Quantity Surveying profession, reverberating throughout the broader mining industry. A deeper understanding of QS services within Mining Capital Projects promises to enhance project management strategies, foster innovation, and bolster industry resilience. The results of the interviews portrayed quantity surveying services as evolving, with core services being the centre point of the evolution. Quantity Surveying services are no longer centred around measuring off drawings and reporting quantities, encapsulating cost reporting, commercial and contractual involvement, and complementing the core functions of project management. Due to the Quantity Surveyors' adaptability, mining capital project clients' reliance on their services has increased. The Quantity Surveyor has become more prominent in the Client's Owners team and is now crucial to the project organogram. This leads to early engagement with quantity surveyors during the initial stages of the project life cycle.

Keywords: Quantity Surveying, Quantity Surveyors, Mining Capital Projects, Evolution, Services.

Introduction

As Charles Darwin famously noted, "It is not the strongest of the species that survives, nor the most intelligent. It is the one that is the most adaptable to change, that lives within the means available, and works cooperatively against common threats." Adaptability is a trait that Quantity Surveyors have had to cultivate due to the demands and nature of the industry. The traditional roles of Quantity Surveyors are secondary to the value-added services they provide to various stakeholders within the industry. A Quantity Surveyor in the mining industry often continues to market their services even after securing appointment on the project.

The role of quantity surveying has evolved since 1836, providing essential services to the fields of architecture and civil engineering, and adapting to the changing demands of these industries over time (Reece, 2017). Although the profession has continued to develop, the earliest recorded quantity surveying firm dates to 1785 in England. While many firms likely existed at that time, Henry Cooper and Sons holds the distinction of being the first documented firm in the history of quantity surveying (Connolly, 2023).

According to Duncan Cartlidge's book (Cartlidge, 2011), in 2001, the Royal Institute of Chartered Surveyors raised concerns about Quantity Surveyors, suggesting that the profession provided minimal or no value to the construction process and was facing decline. Recruitment websites suggest a growing

demand for quantity surveying professionals in the current market. A Business Wire report (2019) highlighted that since 2018, there has been an increase in demand for quantity surveyors within the South African industry. This rise can be attributed to the expanding scope of the profession, greater recognition of the services provided, and the impact these services have on various projects (Anonymous, 2019).

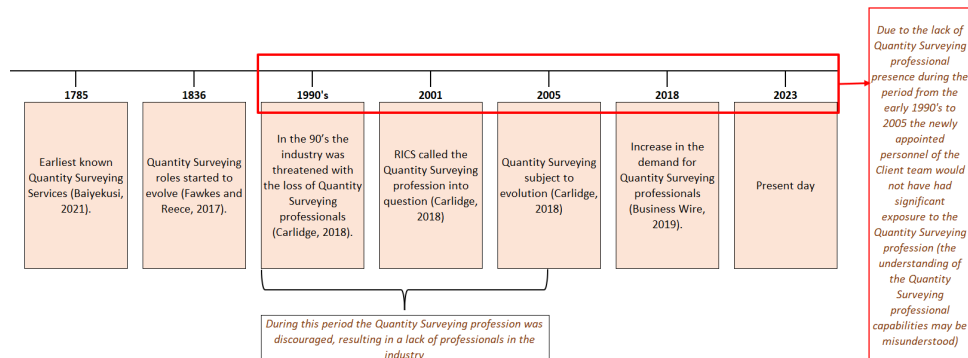


Figure 1: Summary of the quantity surveying background (Cartlidge, 2011)

Often, a quantity surveyor serves as a third-party consultant who advises the Client on matters of cost, quantities, and the commercial aspects of contracting work. In this role, they act as an intermediary between the Client, its consultants, and the contractor executing the scope of work. As the client quantity surveyor, the primary responsibility is to provide advice on pre-contract matters, such as costs and commercial terms, particularly when involved from the project's inception. These costs can be estimated even before the design is fully developed, using in-house databases established by the quantity surveyor (Towey, 2017).

Literature Review

A study conducted in Nigeria, indicated that the Quantity Surveyors services are not fully utilised and recognised when it comes to civil engineering projects (Kaura & Hassan, 2023). Mining projects comprise of civil engineering works. It further compares the role of the QS in Nigeria to the roles in Malaysia and recognises that the Quantity Surveyor in Malaysia is utilised across various platforms due to the understanding of the services (Kaura & Hassan, 2023).

The history of quantity surveying primarily revolves around the measurement of works, which was the profession's original focus (Buys, 2016). The traditional roles of the Quantity Surveyor are often most associated with managing and reporting on the financial position of the projects. These services included:

- Single rate approximate estimates
 - Cost planning
 - Procurement advice
 - Measurement and quantification
 - Document preparation, especially bills of quantities
 - Cost control during construction
 - Interim valuations and payments
 - Financial statements
 - Final account preparation and agreement
 - Settlement of contractual claims
- (Hogg, Ashworth and Higgs, 2013)

However, according to the Willmott Dixon page, the scope of services provided by quantity surveyors today has broadened significantly (Anonymous, 2023). These services now encompass financial, contractual, and commercial management of construction projects both before and during construction. The roles of the Quantity Surveyor according to Towey, now entail the following (Towey, 2017):

- Recommending the most suitable procurement route

- Managing risks through identification and analysis
- Conducting due diligence reporting via scope reviews
- Selecting and recommending construction contracts
- Performing life cycle costing for entire projects or specific components
- Providing advice on dispute resolution
- Contributing to and compiling feasibility studies
- Acting as the Client's representative or agent

Ramdav and Harinarain, assessed the strengths and weaknesses of the Quantity Surveyor. Concluding that main strengths of the Quantity Surveyor is the ability to plan and solve problems, core quantity surveying measuring skills, project viability and interpersonal skills (Ramdav and Harinarain, 2020). These strengths align with the traditional services provided by the Quantity Surveyors where the weaknesses highlighted the need for adaptation which were technical inadequacies of quantity surveyors, resistance to change and lack of knowledge of and about the profession (Ramdav and Harinarain, 2020). However the study highlighted the opportunities as alternate positions for quantity surveyors, the need for quantity surveyors and new and existing roles in and out of the profession which compliment the evolved roles of the Quantity Surveyor.

The study analyses the impact of evolving quantity surveying client services on mining capital projects, specifically in terms of cost, job creation, and the seamless flow of projects from one phase to the next. The analysis involves understanding the influence of these evolving services on the project life cycle, identifying the specific services provided by quantity surveyors, and outlining how these services have evolved over time within the mining sector. Additionally, the study seeks to establish a framework that highlights the benefits of implementing quantity surveying services throughout the different phases of mining projects.

Literature Review

Theoretical Framework

A theoretical framework in research outlines the core concepts and is built on pre-existing theories (Vinz, 2015). To understand the evolution of services that quantity surveyors provide in the mining industry, it is essential to link these services with the end user—in this case, the quantity surveying services offered to the Client.

Success in any industry hinges on client satisfaction, as it reflects the health of the business (Franklin, no date).

Theories related to customer satisfaction, particularly the Comparison Level Theory, align closely with quantity surveying. This theory suggests that clients compare the services received from a quantity surveying firm with their previous experiences or with similar services from other firms (Rana, 2022). The Value Percept Theory is also relevant, as it focuses on the value clients assign to the services provided and the benefits they derive from using those services (Rana, 2022).

If a client is satisfied with the services offered by a quantity surveyor or firm, they are likely to continue using these services for future projects. There is a clear correlation between client satisfaction with quantity surveying services and the demand for such services in future projects.

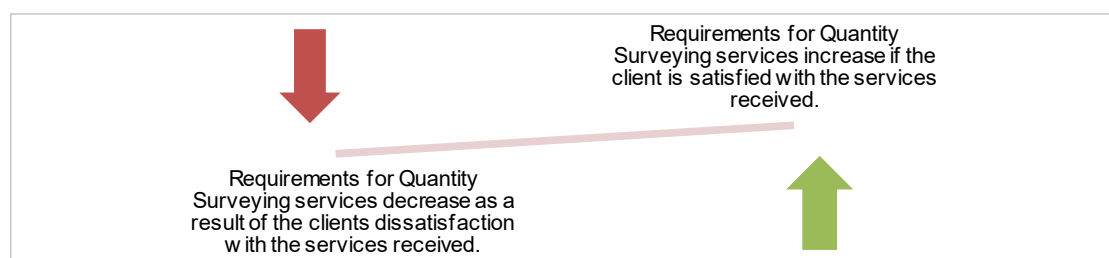


Figure 2: Illustration of quantity surveying services based on client satisfaction

Phases in Project Life Cycles

The project life cycle extends beyond construction projects and is applicable across various industries, though its application may differ. It can be defined as the sequence of phases through which a project progresses (Anonymous, 2020).

According to the South African Council for Quantity Surveying Profession, the following illustrates the various project life cycle phases:



Figure 3: Project life cycle stages

The Mining Industry

The mining industry is focused on extracting resources, precious minerals, and other geological materials from the Earth's surface using established methods and processes (CFI Team, 2018). There are two categories in which mining assets can be classified:

Projects

This phase, also known as capital projects or CAPEX, includes both the feasibility (or exploration) phase and the planning and construction phase. The feasibility phase involves identifying ores that are economically viable for mining. If the project proves viable, it progresses to the planning and construction phase, which involves obtaining necessary permits, conducting economic studies, and updating mining plans (CFI Team, 2018).

Operating Mines

Assets transition to this phase when mining operations are ready to commence. In this stage, ore is extracted, processed, and refined to produce metal. This phase is primarily concerned with the financial model of the operating mine and constitutes the mine's Operating Expenditure (OPEX) (CFI Team, 2018). Once the required ore, as per the study plans, have been extracted the next phase to be focused on is the mine closure (CFI Team, 2018).

Research Design and Methodology

A mono method of data collection, interpretation and analysis was adopted for the purpose of this research. The research study exclusively employed qualitative methodologies, relying on interviews as the method of data collection.

A group of individuals from the mining industry, including quantity surveyors, engineers, and client team personnel, were selected for participation in a 30-minute online semi-structured interview. The questions focused on their experiences with quantity surveying services and the impact these services had on the projects they were involved in. The population group comprised of 40 Quantity Surveyors, 5 personnel from Engineering companies and 13 personnel from Mining houses which included Project Managers, Contracts Managers Scheduler and Planners Cost Controllers Construction Managers and Area Managers.

The interviews provided subjective information and content that was analysed and compared as well contrasted against reviewed literature.

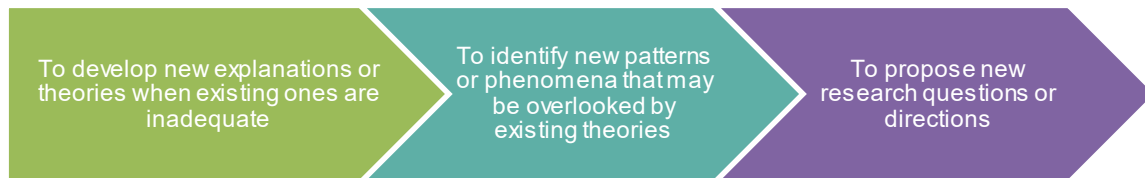


Figure 4: Purpose of abductive research approach

Data collected through qualitative semi-structured interviews was analysed using thematic analysis. This approach involved gathering data from various individuals in the mining industry at a single point in time (Thomas, 2020).

Research Results

The Interviews conducted comprised of the following population groups:

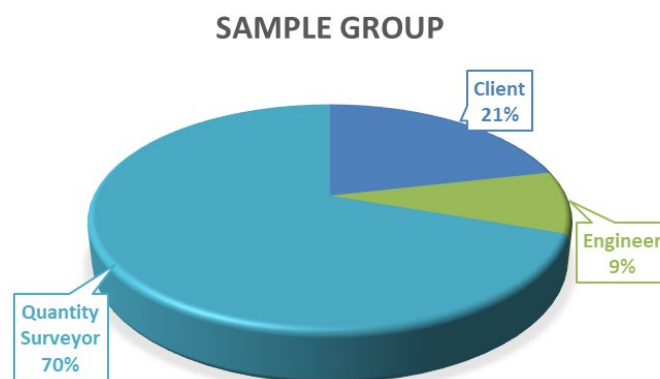


Figure 5: Population formation

The research study targeted a larger population of more experienced individuals in terms of years employed:

Table 4: Respondents working experience in years

Work Experience	< 5	5 - 10	10 – 15	> 15
Frequency	8 (14%)	4 (5%)	12 (20%)	34 (61%)

The research study targeted a larger population of more experienced individuals in terms of years employed in the Mining Industry. Of which all respondents have direct involvement in Mining Capital Projects. Due to the extensive experience of most of the respondents, the transition from entry-level positions to more senior and management roles appeared to be a natural progression. Both the Client and Quantity Surveyors earliest services delivered are comparable and show similarities. Figure 6 below graphically represents the traditional services provided by the Quantity Surveyor compared to the service that the Client receives:

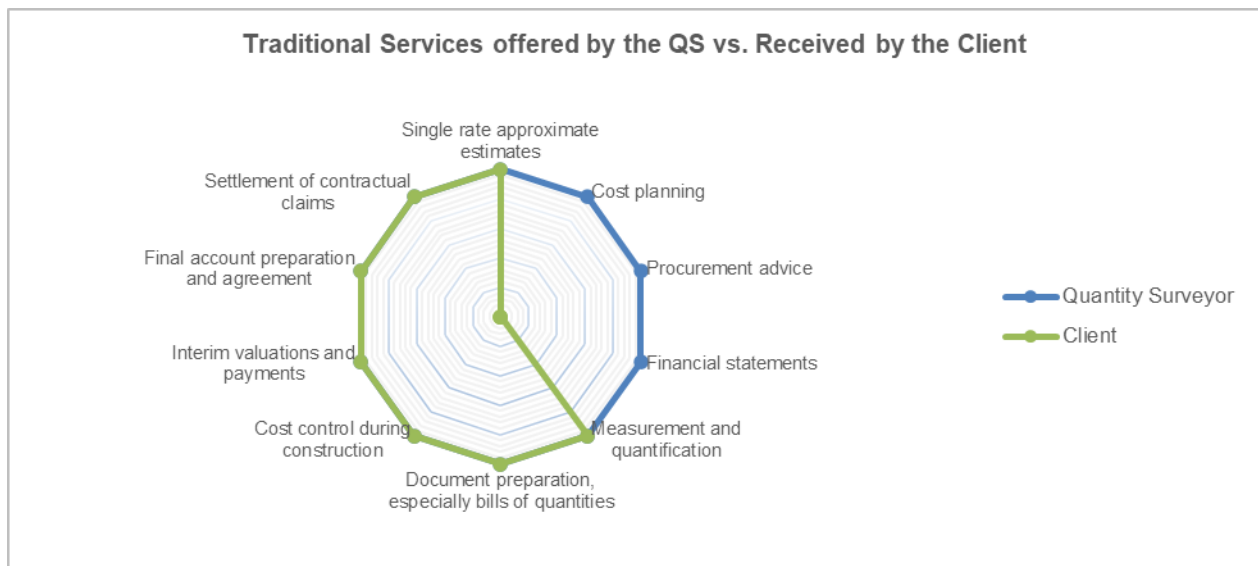


Figure 6: Traditional QS Service - Overlap between Client and Quantity Surveyor

When the respondents were asked to “provide details of other services that you believe a Quantity Surveyors can provide the client/engineer”, the responses correlated with 80% of the evolved services already offered by a Quantity Surveyor. Where the exceptions were Project Management, Scheduling and Planning, Involvement in Project Inception and Lifecycle and Asset and Facilities Management. Clients and Engineers all responded with positive feedback regarding the impact that Quantity Surveying services have had on their projects. Resulting in the implementation of these services from one project to the next. The evolution of services is driven by competition and innovation (Andrikopoulos, Benbernou and Papazoglou, 2012).

Quantity Surveying for Mining Capital Projects is an ever-growing field and will continue to be for the next generations to come due to the evolvement of these services and adaptability of the profession. According to the book by Lee, Trench and Wellis (Hills and Lee, 2024), Element of Quantity Surveying it states that Quantity Surveying is an evolving profession and lends its support to more than just measuring but can fall into buckets of procurement, commercial management as well as project cost management. These predetermined services are those predominantly known to the construction industry as measuring and valuing of Construction works and managing the budget (Admin, 2021).

An overall analysis of the key themes within the interview mainly focuses on the diverse services Quantity Surveyors can offer, such as dispute resolution, sustainability consulting, project management, insurance assessment, cost engineering, risk management, and contract administration. Additionally, it highlights the importance of utilising technology like Artificial Intelligence for efficient project estimation and management.

In the paper “Competencies of Professional Quantity Surveyors in a Developing Economy,” R.N. Nkado highlights the essential competencies required for the future success of Quantity Surveying (Nkado, 2019). These competencies include marketing, advanced financial management, leadership and general management, establishing effective working relationships with emerging local contractors, and managing joint quantity surveying projects. This underscores the potential for Quantity Surveyors to expand their services in these areas.

All quantity surveying respondents answered “yes” when asked if they believe Quantity Surveying services have evolved, however it was evident from the interviews that the Quantity Surveyor is not used to their full potential.

Quantity Surveying service offered by the Quantity Surveyor to the Client and/or engineer based on the interview questions comprised of the following responses:

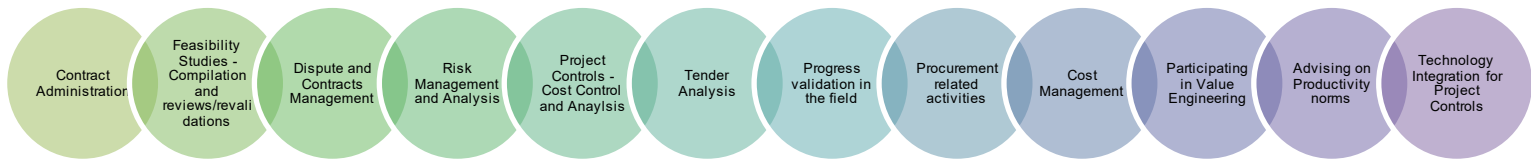


Figure 7: Additional Services offered by the Quantity Surveyor

In response to a question about additional services that a quantity surveyor can offer to clients or engineers, it became clear that the evolved services, as illustrated in Figure 7, are not fully understood by the Client. The Client is primarily familiar with the standard quantity surveying services depicted in Figure 8. This suggests that the additional services provided by the quantity surveyor are not being effectively demonstrated or utilised by the Client and/or engineer. Thus, restricting the growth of the Quantity Surveyors services on projects.

The positive feedback received from Clients and Engineers support the Customer satisfaction theory. The Value percept theory is applicable here since the Client assigns value to the services provided for by the Quantity Surveyor as well as the benefit of utilising the services provided (Rana, 2022). Therefore, the services of the Quantity Surveyor are adopted on future projects.

The generic Quantity Surveying services encapsulated in the book titled Willie's Practice and Procedure for Quantity Surveyor correlated with the early on services that the Quantity Surveyor provided the Client and/or engineer as per Figure 8.

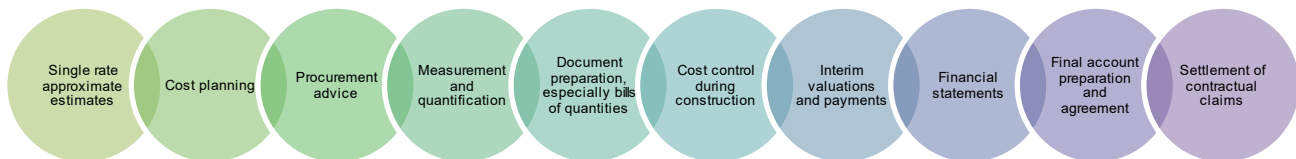


Figure 8: Traditional Quantity Surveying Services (Hogg, Ashworth and Higgs, 2013)

Conclusion

Despite the longevity of the Quantity Surveying profession there is still a lack of understanding regarding the evolution of client quantity surveying services in mining capital projects. This often results in inadequate implementation throughout the project life cycle, thereby reducing their overall effectiveness. Quantity Surveyors are often found on projects still having to explain their role to various stakeholder because of the poor implementations of their services.

Comparing Figures 7 and 8 reveals that the services provided by the client quantity surveyor have evolved. This evolution is associated with the broader development of quantity surveying services. As project teams have expanded and the need for detailed costing analysis has increased, quantity surveyors are now being involved from the start of the project cycle. This early involvement facilitates continuity and smooth transitions between project phases.

The impact of this evolvement is associated with the customer satisfaction theory known as value percept theory where the Client has assigned value to the services and continues to utilise the services on future projects. The Quantity Surveying client services on mining capital projects have evolved to cater for the demands of the Client and the industry requirements. Clients have become more reliant on the services offered by the Quantity Surveyors as depicted in Figure 7 due to their ongoing engagement.

Limitations

- Quantity Surveying in Mining has limited information available for research reference purposes. In comparison to the Commercial/Architectural field the knowledge on Quantity Surveying in Mining does not contain the depth of information required to conceptualise topics and requires further research to be conducted.
- The data collected was subjective and not based off scientific data but rather the experience of individuals within the field, thus making the data collected unobjectively verified.

Recommendations

There is a continued need to promote quantity surveying services in mining capital projects. The interviews revealed that the value-added services offered by quantity surveyors are often performed by other professionals who may lack the specialised databases and benchmarks necessary for accurate information. Mining companies need to be made aware of the significant value that quantity surveyors bring to capital projects, particularly during the early phases of the project life cycle.

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Assessing Sustainable Construction Competency Gaps Among Quantity Surveyors in Zimbabwe

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Abstract

This research aims to enhance the quantity surveyor's role in implementing sustainable construction practices by determining the required quantity surveyors' sustainable construction competencies and establishing the significant differences due to the type of organisation. A deductive approach was employed, utilising a structured questionnaire survey to gather quantitative data from quantity surveyors regarding the competencies necessary for sustainable construction and effective methods for their development. Census sampling was used to ensure comprehensive representation, achieving a response rate of 70.7%. The data were analysed using the Mann-Whitney U test and mean score calculations to identify significant differences in competencies across various organisational types. The results indicated that most quantity surveyors acknowledge the importance of sustainable construction. Key competencies identified include measurement and costing, sustainable materials and technology, value engineering, and building information modelling. The analysis also revealed a competence gap among different quantity surveyor designations, highlighting disparities in their ability to implement sustainable practices effectively. This study was limited to quantity surveyors in Zimbabwe consulting firms and contracting organisations. Future research could expand to include qualitative interviews and surveys with a broader range of construction stakeholders, including architects, engineers and project managers, to gain a more comprehensive understanding of the competencies needed for sustainable construction. The insights gained from this study can help quantity surveyors remain relevant in the evolving built environment. Policymakers may use these findings to develop targeted regulations and allocate resources to promote sustainable construction. Additionally, construction companies can enhance project efficiency and ensure regulatory compliance by integrating these essential sustainable practices into their operational frameworks. This study contributes valuable insights into the sustainable construction competencies required by quantity surveyors, thereby fostering improved implementation of sustainable practices within the industry.

Keywords: Sustainable Construction, Sustainable Construction Competencies, Quantity Surveyor, Zimbabwe.

Introduction

The built environment is a major consumer of natural resources, significantly impacting our globe. According to the World Economic Forum (2024), the construction industry is the largest global consumer of resources, utilising approximately 50% of the world's steel production and consuming around 3 billion tonnes of raw materials annually for building products. This consumption leads to substantial environmental degradation, necessitating the urgent adoption of sustainable construction practices (Hussin et al., 2013; Sakaa et al., 2019; Zeadat, 2024). However, many developing nations, including Zimbabwe, have fallen behind in implementing these practices, contributing to slow progress toward sustainability in the construction sector (Osuizugbo et al., 2020; Ohene et al., 2019).

In Zimbabwe, the uptake of green building technologies has been very slow, and the contribution of the built environment to sustainable development remains minimal (Chingwenya and Zhakata, 2021). Although the significance of sustainable construction practices is well acknowledged as essential for

advancement (Lima et al., 2023; Aghimien et al., 2022; Zeadat, 2024), many quantity surveyors lack the necessary knowledge and skills to support this development (Haron et al., 2017; Bolade-Oladepo et al., 2020). Consequently, it is critical to equip quantity surveyors with the relevant competencies for sustainable development (Wong, 2017). However, there exists a significant gap in identifying the specific competencies required for quantity surveyors in this context (Chandramohan et al., 2018; Babalola et al., 2022).

Previous research has highlighted considerable knowledge gaps in the role of quantity surveyors in sustainable development and construction (Cartlidge, 2017; Chandramohan et al., 2020; Shanika et al., 2022). While studies such as those by Chigwenya et al. (2021) and Moyo et al. (2024) have tried to situate the Zimbabwean construction industry within the context of sustainable practices, they have not specifically investigated the competencies required for quantity surveyors in sustainable construction.

Therefore, this study aims to address this gap by determining the sustainable construction competencies necessary for quantity surveyors in Zimbabwe. It focuses on two distinct designations of quantity surveyors: consultants and contractors, given their direct influence on quantity surveying roles within the construction industry (Yap, 2022). By equipping quantity surveyors with the necessary competencies, we can enhance the implementation of sustainability in construction projects, ultimately contributing to the development of sustainable infrastructure and mitigating long-term environmental impacts (Davies et al., 2017; Willar et al., 2021).

The subsequent sections of this paper will review relevant literature on the required sustainable construction competencies, followed by a detailed description of the methodology employed in this research. The data will be presented and analysed, leading to conclusions and recommendations aimed at determining the required quantity surveyor sustainable construction competences which would enhance the role of quantity surveyors in sustainable construction.

Literature Review

Sustainable construction

Sustainable construction can be defined as ensuring that all construction activities are carried out in a sustainable manner, from the beginning (planning) to the end stages (Ismail et al., 2017). Sustainable construction involves planning and carrying out all construction activities in a sustainable manner, considering economic, social, and environmental implications (Willar et al., 2021). The key principles of sustainable construction are developed and divided into seven aspects of reduce, reuse, recycle, protect nature, eliminate toxins, apply life-cycle costing and focus on quality (Kibert, 2016).

Quantity surveyors' sustainable construction knowledge and the required competencies

Sustainable construction has become a critical focus within the construction industry, necessitating a change in the competencies required of quantity surveyors (Qs). This literature review explores the existing knowledge of sustainable construction among quantity surveyors, highlighting the evolving competencies needed in this field.

The knowledge of sustainable construction among quantity surveyors is often reported as inadequate. For example, Daniel (2018) emphasises that many quantity surveyors lack essential skills and knowledge related to sustainable practices. Higham and Thompson (2015) further prove this point by identifying a significant discrepancy in the implementation of sustainable construction practices in the UK, attributing it to negative perceptions and insufficient knowledge among construction professionals. Conversely, a study by Mashwama et al. (2020) in South Africa indicates that while construction professionals are aware of sustainable practices, their implementation remains partial, suggesting a need for deeper engagement with these concepts.

This lack of comprehensive knowledge is particularly evident in Zimbabwe, where Moyo et al. (2023) argue that sustainability concerns are gaining traction alongside traditional competencies. However, there remains a critical gap in understanding how these sustainability practices are effectively integrated into the work of quantity surveyors in the Zimbabwean context.

The traditional competencies of quantity surveyors are rapidly changing to meet new demands. As noted by Wanda et al. (2016) and Wong (2017), there is a shift away from conventional practices, necessitating the acquisition of new skills. Quantity surveyors are increasingly expected to demonstrate proficiency in how sustainability seeks to balance economic, environmental and social objectives at global, national and local levels, in the context of the built environment (Royal Institute of Chartered Surveyors, 2018).

Chandramoham et al., (2020) discovered that construction technology and environmental services, computer literacy, ethics and professional practice, leadership and management, and measurement and costing are areas in sustainable construction that are important to quantity surveyors; therefore, proficiencies in these areas need to be developed. Ekanayake et al., (2021) suggested possible quantity surveyor roles required for green building development which include working on green lease and green finance, measuring carbon footprint, whole life costing, environment services. According to Omotayo, (2022), advanced sustainability services offered by quantity surveyors in Singapore are feasibility studies for green projects, cost estimation and cost planning for green projects, preparing bill of quantities for green projects, life cycle cost analysis, carbon footprint assessment, advice on green mark scheme and property performance reporting. In view of the existing literature the study will consider the competencies variables shown in table 1 below.

Table 1: Sustainable construction competencies considered for the study

Sustainable construction competencies	Source
Building information modelling	Mashwama et al., (2020); Shanika et al., (2022); Sakaa and Chan (2019), RICS (2018)
Collaboration and communication	Ayarkwa et al., (2022), RICS (2018)
Environmental assessments	(Ekanayake and Bandara, 2021)
Life cycle cost assessment	Wong (2017); Bolade-Oladepo et al., 2020).
Measurement and costing	Chandramohan et al., (2020); Omotayo et al., (2022)
Risk management	(Babalola et al., 2022)
Sustainable materials and technologies	Shanika et al., (2022)
Value engineering	Babalola and Onososen, (2022)

Building Information Modelling (BIM) is a pivotal tool in the construction industry, representing a digital framework that encompasses the physical and functional characteristics of facilities. This technology facilitates collaboration among stakeholders throughout the project lifecycle, enabling improved communication and efficiency. BIM enhances decision-making regarding sustainable practices, allowing quantity surveyors to accurately estimate costs and assess the sustainability of materials (Ahsan et al., 2023). However, in Zimbabwe, the adoption of BIM is often limited as many quantity surveyors continue to rely on traditional methods rather than embracing this innovative approach. This hesitation is compounded by a lack of training and resources, as noted by Gilchrist et al. (2021), highlighting the need for a more robust understanding of BIM applications within the context of quantity surveying (Keung, 2022).

Effective collaboration and communication are essential competencies for quantity surveyors engaged in sustainable construction. These skills promote productive interaction among project stakeholders, enabling the integration of sustainable practices into project planning and execution. Collaboration among various stakeholders, including architects, engineers, and clients, is essential for successful sustainable construction (Nyame and Egbu, 2023). Quantity surveyors must advocate for sustainability and educate stakeholders on its benefits. Sakaa et al. (2019) highlights the importance of open communication in fostering innovative solutions.

The knowledge of sustainable construction technologies such as green building rating systems and their application in project specifications is a key competency for quantity surveyors (Yap, 2022). However, quantity surveyors frequently lack in-depth knowledge about the environmental impact of various building materials, their full life cycle assessments, and innovative sustainable construction technologies, resulting in a gap in understanding of the environmental impact and life cycle assessment (Windapo, 2014). Environmental assessments are critical in evaluating the potential impacts of construction projects on the environment, guiding decision-making toward more sustainable practices. These assessments enable quantity surveyors to advise clients on regulatory compliance and the benefits of adopting environmentally friendly solutions.

Life Cycle Cost Assessment (LCC) is an essential method that evaluates the total cost of ownership of a project over its lifecycle, encompassing initial, operational, and disposal costs. This approach is crucial for supporting sustainable decision-making, as it illustrates the long-term cost savings associated with sustainable practices (Benson, 2018). However, a study by Opawole et al. (2020) identified significant barriers to LCC application in developing contexts, including insufficient expertise and awareness among quantity surveyors. In Zimbabwe, this lack of understanding can impede the effective implementation of LCC, making it essential to enhance training and education on this competency. Addressing these challenges will require articulating a basis exclusively intended to address the challenges. This highlights the need for further research to address the gaps in knowledge and regulation within life cycle cost and whole life cost

Accurate measurement and costing are foundational competencies for quantity surveyors, involving the quantification of materials and labour required for construction projects. Precision in measurement is crucial for effective budgeting and for ensuring the feasibility of sustainable materials and technologies (Towey, 2012). In Zimbabwe, however, inconsistencies in measuring sustainability-related products can pose challenges, leading to difficulties in cost estimation and project budgeting (Cartlidge, 2017). Quantity surveyors must refine their measurement techniques to better incorporate sustainable practices and ensure accurate financial planning (Chandramoham et al., 2018).

Risk management is another vital competency that encompasses identifying, assessing, and mitigating risks associated with construction projects. For quantity surveyors, effective risk management can enhance the value of sustainable projects by reducing uncertainties and potential losses (Hackett et al., 2016). According to George (2020) there is a lack of knowledge of the array of risk identification and analysis techniques available. Therefore, the inconsistent data and a lack of comprehensive training in risk management practices can hinder the ability of quantity surveyors to manage risks effectively. Strengthening training programs in this area is essential to empower quantity surveyors to navigate the complexities of sustainable construction.

Knowledge of sustainable materials and technologies is crucial for quantity surveyors, enabling them to recommend environmentally friendly options that align with project goals. Familiarity with these materials supports informed decision-making and promotes the adoption of sustainable practices (Babalola and Onososen, 2022). However, challenges persist in Zimbabwe, where limited availability and higher costs of sustainable materials can impede their widespread adoption. Additionally, many quantity surveyors lack knowledge of green products, which limits their effectiveness in promoting sustainability (Wong, 2017; Adesi et al., 2023). While sustainable materials are widely known in global markets, their adoption poses challenges, especially in developing countries. Adesi et al. (2023) point out that pricing and availability of these materials complicate their use by quantity surveyors. Furthermore, Wong (2017) notes that many quantity surveyors lack knowledge about green materials, limiting their ability to promote sustainable practices effectively.

Value Engineering (VE) is a systematic approach aimed at enhancing project value by optimising functions and reducing unnecessary costs. The adoption of value engineering includes the ability to identify potential problems early, eliminating unnecessary designs, reducing waste, and ensuring that the project is delivered in the most cost-effective way (Hariram et al., 2023). Despite its benefits, the actual utilisation of VE among construction professionals remains moderate, as highlighted by Akinsiku et al. (2018). According to Aghimien et al., (2018) in Nigeria construction professionals possess a significant amount of understanding about VE practice, but the actual utilisation of the practice remains average. In Zimbabwe, quantity surveyors may face similar challenges in fully embracing VE principles, underscoring the need for further training and awareness in this area. Therefore, it is essential for quantity surveyors to attain competences in value engineering to enhance sustainable construction.

Research Methodology and Method

The study adopted a positivist philosophy, which supports the objective collection of quantitative data to derive generalisable findings. This approach is appropriate for examining the competencies of quantity surveyors in sustainable construction, as it allows for the identification of measurable relationships and patterns. Similar methodologies have been employed in previous research by Dada (2015), Babalola et al. (2022), and Adesi et al. (2023), validating the choice of this framework.

The target population for this study consisted of practicing quantity surveyors, the sampling frame consisted of quantity surveyors from construction and consulting firms in Zimbabwe (Yap, 2022). A census sampling method was adopted, aiming to gather data from the entire population of 92 respondents across 19 registered firms with the Zimbabwe Institute of Quantity Surveyors (ZIQS) and 73 Category A and B firms registered within the Construction Industry Federation of Zimbabwe (CIFOZ). This comprehensive approach enhances the representativeness of the sample and ensures a thorough understanding of the competencies required within the entire industry.

Data collection was executed using a structured questionnaire, elected for its success in capturing consistent responses and the convenience it offered when collecting information from many participants within a period. Questionnaire was developed using literature review and a conceptual framework was created to ensure that the questionnaire covered the important questions. The questionnaire comprised two sections: Section A collected demographic information, including gender, type of organisation, position, educational qualifications, and work experience. Section B focused on determining the important various sustainable construction competencies, utilising a five-point Likert scale (1 = not at all important to 5 = very important) to rank responses.

To ensure validity, content validity was utilised to assess whether the questionnaire adequately covered the construct of sustainable construction competencies. The study engaged experts in quantity surveying and sustainable construction to review the questionnaire items and ensure they align with the competencies being measured. Furthermore, a pilot survey was conducted with five experts in quantity surveying and sustainable construction working in Zimbabwe. All the queries were clarified until the feedback from the pilot test indicated that participants understood the questions and instructions, confirming the instrument's validity prior to the main data collection phase.

Cronbach's alpha is a reliability coefficient that was used to measure reliability. The nearer the Cronbach's alpha is to 1, the higher the internal consistency reliability. The reliability of the questionnaire was established through a Cronbach's Alpha, a value of 0.840 was obtained, exceeding the threshold of 0.70, thereby confirming internal consistency (Jonson, 2014).

To assess the normality of the data distribution, the Kolmogorov–Smirnov test was employed, as the sample size exceeded 50. The test yielded a p-value of 0.000, indicating a deviation from normal distribution and necessitating the use of non-parametric tests for further analysis (Mishra et al., 2019).

Data analysis was performed using descriptive and inferential statistical techniques. Mean scores and standard deviations were calculated to rank the essential competencies for quantity surveyors in sustainable construction. For a mean score of 1.00-1.89, the importance of response was considered as not at all important; 1.90-2.69 slight important; 2.70-3.49 somewhat important; 3.50-4.29 important; and 4.30-5.00 very important (Hadiyanto and Suratno, 2015; Zaki and Ahmad, 2017).

The Mann-Whitney U test was specifically utilised to explore significant differences in sustainable construction competencies between quantity surveyors working for construction companies against those in consulting firms. The results indicate the p-values associated with each variable, with a p-value ≤ 0.05 signifying a statistically significant difference (Okoye et al., 2022; Moyo et al., 2023).

Results and Discussion

Demographics of respondents

As shown in Table 2 below, a total of 92 questionnaires were distributed, with 65 questionnaires returned and deemed usable, resulting in a response rate of 70.7%. Response rates around 70% and higher are generally considered acceptable (Jonhson and Christensen, 2014). Contractors had the highest representation (78.5%) since the construction companies made up 76% of the research population. Most respondents hold the position of Quantity Surveyor (52.8%), followed by Project Manager (30.6%) and Estimator (16.7%). This aligns with the idea that Quantity surveyors had multiple responsibilities in the construction industry (Wao and Flood, 2016). Most respondents (83.1%) have a degree, while a smaller proportion (16.9%) have post graduate qualifications. This is like previous studies by (Ekung and Okonkwo, 2015) which revealed that in the United Kingdom there are very few progressions into MSc and PhD, as students from QS background often find the MSc level core QS modules unappealing as it simply summarises the knowledge gained during the undergraduate level.

Respondents are evenly distributed across different levels of work experience, with 35.4% having below 5 years, 30.8% having 5 to 10 years, and 33.8% having above 10 years of practice. Having respondents with different levels of experience enhances the representativeness of the findings.

Table 2: Respondents information

Description	Frequency (No.)	Percent (%)
Industry sector		
Contractor	51	78.5%
Consultant	14	21.5%
Total	65	100.0%
Position in the organisation		
Quantity surveyor	31	47.7%
Estimator	12	18.5%
Project manager	22	33.8%
Total	65	100.0%
Education level		
Undergraduate	54	83.1%
Postgraduate	11	16.9%
Total	65	100.0%
Work experience		
Below 5 Years	23	35.4%
5 to 10 Years	20	30.8%
Above 10 Years	22	33.8%
Total	65	100.0%

Quantity surveyor required sustainable construction competencies

Mean score was used to rank the required quantity surveyor sustainable construction competences. Most of the competencies were ranked as very important with a minimum mean score of 4.30 and above.

Table 3: Quantity surveyor required sustainable construction competencies

Competencies	Overall (N=65)		
	Mean	Std. Deviation	Ranking
Measurement and costing	4.43	.637	1
Sustainable materials and technologies	4.42	.808	2
Value engineering	4.37	.961	3
Building information modelling	4.32	.731	4
Risk management	4.26	.923	5
Environmental assessments	4.09	.631	6
Life cycle cost assessment	4.06	.864	7
Collaboration and communication	3.80	.922	8

Table 3 above presents the mean scores, standard deviations, and rankings of the competencies deemed essential for quantity surveyors, based on responses from 65 participants. The analysis of mean scores reveals that the top three competencies among the respondents include measurement and costing, sustainable materials and technologies and value engineering. Where measurement and costing emerged as the top competency, indicating a strong consensus on its importance in the field. This finding is consistent with previous studies by Chandramohan et al., (2020) that highlight the critical role of accurate measurement and cost estimation in project success as it directly impacts project feasibility and financial planning.

Sustainable materials and technologies were considered very important, reflecting a growing emphasis on sustainability in construction practices. This aligns with current trends emphasising environmentally responsible choices in the industry. Although, Ma and Luu (2013), highly rated the understanding of sustainable green materials as one of the crucial competencies required for quantity surveyors. The implementation of sustainable materials and technologies in developing countries is still low due to

lacking green building skills, high capital cost, nonexistence of building code and regulations and absence of government incentives and support (Eze et al., 2023).

Value engineering and Building information modelling were also ranked very important competencies, underscoring the need for quantity surveyors to enhance project efficiency and effectiveness through innovative practices. In agreement, Sakaa et al., (2019) and Datta et al., (2023) stressed the importance of quantity surveyors understanding and implementing BIM can enhance the efficiency, cost-effectiveness, and environmental performance of construction. Study by Aghimien et al., (2018) also emphasised that the adoption of value engineering is an integral part of construction projects which is vital in achieving sustainability in construction projects.

Risk management was considered important highlighting the necessity of identifying and mitigating potential project risks, a concern echoed in literature by Hackett et al., (2016). Babalola et al., (2022) also identified risk management as an important quantity surveyor competence. The competencies of Environmental assessments and Life cycle cost assessment were classified important thus, further emphasising the importance of full approaches in project evaluation, supporting findings from Chandramohan et al., (2020) and Ekanayaka et al., (2021). Collaboration and communication remain important, although it ranks lower compared to other competencies. This suggests a potential area for improvement, as effective communication can enhance team dynamics and project outcomes. However, the result is in contrast with findings by Yap et al., (2022) where communication was ranked a very important evolving competence required by quantity surveyors.

Significant differences due to designation

A Mann Whitney U test was utilised to determine the significance of the required quantity surveyor sustainable construction competencies to improve the implementation of sustainable construction practices. All the competencies had a significance level which is < 0.005 . This shows that all the competencies can effectively improve the role of quantity surveyors in the implementation of sustainable construction practices.

Table 4: Summary of Mann-Whitney U test results on designations for the required competencies

Competencies	Designation mean rank		Sig.
	Consultant QS mean rank	Contractor QS mean rank	Mann Whitney U results
Measurement and costing	41.71	30.61	0.028
Sustainable materials and technologies	38.46	31.50	0.016
Value engineering	38.39	30.85	0.013
Building information modelling	37.43	31.78	0.026
Risk management	35.61	32.28	0.049
Environmental assessments	34.21	32.67	0.035
Life cycle cost assessment	30.93	32.94	0.046
Collaboration and communication	37.07	31.88	0.030

The competencies of measurement and costing, sustainable materials and technologies, value engineering, building information modelling, risk management, environmental assessments, life cycle cost assessment, and collaboration and communication show statistically significant differences based on the designations of consultants and contractors in quantity surveying. Measurement and costing received the highest ranking, indicating that both designations recognise the importance of accurately measuring and costing green building projects. The significant difference suggests that Consultant QS place a greater emphasis on this skill compared to Contractor Qs, thus indicating their focus on precise cost estimation for sustainable projects. The strong emphasis on this competency suggests that training programs for Contractor QS should enhance skills in green measurement techniques. As sustainability becomes increasingly important, ensuring that all QS can competently manage these aspects will be vital for project success (Chandramohan et al., 2020). The importance on value engineering shows the need to improve project costs while maintaining quality. The significant difference shows a greater focus by Consultant QS, suggesting they are more involved in strategic cost management. Therefore, it is important to train Contractor QS to incorporate value engineering principles into construction projects. Equipping them with these skills can lead to enhanced project efficiency and better decision-making

on-site, ultimately benefiting project outcomes (Aghimien et al., 2018). Building information modelling is another area that highlights the consultant's role in integrating technology into the project lifecycle. Quantity surveyors should advocate for the adoption of BIM technologies and seek training that incorporates local practices and standards to enhance project outcomes and contractors can improve collaboration and efficiency on-site, aligning with the industry's digital transformation (Sakaa et al., 2019; Datta et al., 2023). Risk management is essential for consultants, who often oversee project oversight, while environmental assessments are recognised by both groups but rated higher by consultants, suggesting their role in ensuring compliance with sustainability standards. Training programs should focus on enhancing risk management skills to identify and mitigate the uncertainties in the construction sector (Hackett et al., 2016). Life cycle cost assessment reveals a slight preference among contractors, indicating their emphasis on practical financial implications during the construction phase. Collaboration and communication, though ranked lower, are acknowledged by both groups, suggesting that strengthening these skills is vital for successful project execution.

Conclusion

This study aimed to identify the essential competencies required by quantity surveyors to effectively implement sustainable construction practices in Zimbabwe, while also examining significant differences in perceptions based on professional designation. The findings highlight that the key competencies needed include measurement and costing, sustainable materials and technologies, value engineering, and building information modelling.

The research also indicates significant disparities in how Consultant Quantity Surveyors (QS) and Contractor QS perceive these competencies. Consultant QS rated competencies such as the measurement and costing of green buildings, sustainable materials, and value engineering more highly, reflecting their roles in detailed design and project planning. Conversely, Contractor QS placed less emphasis on these competencies, likely due to their primary focus on project execution and implementation.

This variance stresses the necessity of designed training programs that address the distinct needs and responsibilities of each type of quantity surveyor within sustainable construction projects. Through supporting professional development in line with these findings, stakeholders can enhance the effectiveness of quantity surveyors in promoting sustainable practices in the built environment.

Furthermore, the implications of this research extend beyond Zimbabwe, suggesting that similar strategies could be beneficial in other developing countries facing challenges in sustainable construction. Future research should explore the effectiveness of targeted training initiatives and assess their impact on sustainable construction practices.

In conclusion, this study highlights the vital role of competency development in advancing sustainable construction. By equipping quantity surveyors with the necessary skills, we can create a more sustainable built environment, ultimately contributing to broader environmental and societal goals.

Recommendations

- Quantity surveyors are encouraged incorporate modern construction methods into project planning and execution. This is in line with the conclusion's emphasis on the necessity of enhancing sustainable competencies among quantity surveyors, ultimately improving sustainability performance in the built environment.
- Tertiary institutions should include modules on sustainable construction practices and competencies. This would support the call for improved education and training, equipping future professionals with the skills necessary to implement sustainable practices effectively.
- Establish targeted training programs aimed at bridging the knowledge gap among quantity surveyors regarding sustainable construction practices. This action directly responds to the conclusion's claim that specific training is vital to meet the specific needs of different types of quantity surveyors, thus enhancing their effectiveness in sustainable projects.
- Policymakers should establish and enforce regulations that mandate the inclusion of sustainable practices in construction projects. This recommendation supports the importance of enhancing the capacity of quantity surveyors, enabling them to advocate for sustainable construction practices through regulatory frameworks.

- Construction firms should invest in technologies that improve the planning, execution, and management of sustainable projects such as BIM. Investing in technologies that enhance sustainable practices, firms can support the importance that is emphasised on the critical role of quantity surveyors in advancing sustainability within the construction industry.
- Create platforms for collaboration between quantity surveyors, contractors, and consultants to share best practices and innovations in sustainable construction. This recommendation outlines the need for shared understanding among different types of quantity surveyors, promoting collective efforts toward sustainability.

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Assessing the Constraints and Strategies for Effective Adoption of Labour-only Construction Contracts in a Hyperinflationary Environment in Zimbabwe

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Abstract

This study aims to assess the constraints and strategies for effectively adopting labour-only construction contracts to enhance project delivery in Zimbabwe's hyperinflationary economy. This was prompted by the failure of contractors to complete construction projects promptly within Zimbabwe's hyperinflationary environment. A questionnaire survey was employed to collect quantitative data from 130 randomly selected respondents comprising registered professional quantity surveyors, engineers, architects, and project managers in Zimbabwe. The data was analysed using mean scores and their ranking. The study identified late delivery of construction materials, longer construction periods and reduced contractor's profit as major constraints of effective adoption of labour-only contracts. Further, the findings revealed five key strategies for effectively adopting labour-only contracts in Zimbabwe: subcontracting to smaller construction companies, production output-based remuneration as opposed to hourly-based remuneration, use of efficient modern construction methods and payment of contractors using stable currencies. Further, labour-only contracts should be augmented by a vibrant procurement team facilitating quick planning and decision-making. The Zimbabwean setting from which the data was collected and the mono-method quantitative approach could limit the generalisability of the findings to other settings due to contextual differences and lack of triangulation of findings. Employing the identified strategies for adopting labour-only contracts mitigates contractors' financial risks during hyperinflation, thus reducing project cost overruns and ensuring that projects are completed promptly. There is a paucity of literature on the strategies for effectively adopting labour-only construction contracts within the Zimbabwean context. Hence, the findings will assist construction industry stakeholders in effectively adopting labour-only contracts to enhance effective project delivery during a hyperinflation environment in Zimbabwe and similar contexts.

Keywords: Construction Project Delivery, Hyperinflation, Labour-only Contracts, Procurement Strategies, Zimbabwe.

Introduction

Despite the construction industry being instrumental in catalysing socio-economic development of nations, the nature of the business environment is a key determinant of project success worldwide (Dhliwayo, Musonda, Gumbo & Kaisara, 2024; Dhliwayo, Musonda & Gumbo, 2022a, Santoso, Permana & Abdullah, 2021). In a stable business environment, Dhliwayo, Musonda, Gumbo and Kaisara (2024) argue that the smooth operation of contractors is promoted due to predictable operational procedures and profit margins. On the contrary, research shows that it is daunting to successfully deliver projects in an unstable business environment due to the volatility of labour cost, material prices and other variables required for project execution (Wang, Cui & Dong, 2023; Bikitsha & Amoah, 2022). Therefore, hyperinflation is among the worst catastrophes impeding the effective project delivery in most developing countries (Ebekozi et al., 2024; Starwind, 2022; Chen, Kumara & Sivakumar, 2021). This phenomenon entails unprecedented deterioration of the currency of a country (Starwind, 2022). In recent years, most developing countries have been perturbed by the deleterious impact of hyperinflation on construction project delivery (Chen, Kumara & Sivakumar, 2021). Generally,

the construction industry is highly sensitive to inflationary pressures due to its overdependence on other economic sectors like financial institutions, material suppliers and other service providers (Jayatilaka, Waidyasekara & Sirimewan, 2021). Notably, in a hyperinflationary environment, large sums of money can be invested and locked in unusable incomplete projects (Siami-Namini & Hudson, 2019). Consequently, enormous time and cost overrun are incurred on construction projects (Musarat et al., 2021). Siami-Namini and Hudson (2019) confirm that hyperinflation erodes earnings of low-income earners, of which a significant number of such earners work in the construction industry. As a result, this leads to the poor performance of the construction industry as both the contractor and employees grapple with the loss of income (Pandey, Khan & Scholar, 2023). In Zimbabwe, hyperinflation has been incessant since 2000 and has culminated in the loss of investors, budget deficits, skilled labour and ultimately underperformance of the construction industry (Moyo & Crafford, 2010; Coomer & Gstraunthaler, 2011). Given the unprecedented series of severe hyperinflation which characterised Zimbabwe over the past two decades, the question posed by Coomer and Gstraunthaler (2011) a decade ago on whether this is an isolated economic novelty or whether this economic turbulence plagued other countries, remains. Of course, countries like Ukraine (Dabrowski, 1994) once experienced hyperinflation after the decomposition of former Soviet Union in 1991, though the impact might not be equated to the Zimbabwean case.

It is noteworthy to mention that the volatility of construction materials in a hyperinflationary environment has forced most contractors to shun supply and fix contracts (Awodele et al., 2019; Outram, 2022; Mhlanga & Ndhlovu, 2021). On the contrary, there has been proliferation of labour-only contracts in a bid to reduce risks on the side of contractors (Cunningham, 2017). This is corroborated by Mhlanga and Ndhlovu (2021) who suggest that labour-only contracts shift risks related to the procurement of materials from the contractors to the clients, thus reducing contractors' financial burden and possible losses. In Nigeria, Awodele et al. (2019) posit that labour only contracts can enhance huge time savings on construction projects. Due to the mentioned benefits, Akinkunmi, Aghimien & Awodele (2018) claims that labour-only contracts have gained traction in Nigeria. Similarly, Outram (2022) claim that most developing countries are increasingly adopting labour-only contracts due to the unpredictability of construction materials and other resources in hyperinflationary environments.

Despite labour-only contracts being largely considered the best procurement methods in hyperinflationary environments as previously noted, there is a myriad of constraints impeding their effective implementation in most developing countries (Akinkunmi, Aghimien & Awodele, 2018; Awodele et al., 2019). Critically, accurate cost estimation of labour is reportedly insurmountable in a hyperinflation (Pandey, Khan & Scholar, 2023). This emanates from rapid changes in prices across economic sectors which invariably affect wages of construction employees. Due to the dynamic macroeconomic environment, Pandey, Khan and Scholar (2023) claim that shortage of materials and costly delays are rampant during project execution with consequential impact on labour cost. Considering the importance of infrastructure development and the adversarial impact of hyperinflation (Pandey, Khan & Scholar, 2023), exploring strategies to promote the effective implementation of labour-only contracts is imperative in a bid to enhance project delivery in hyperinflationary environments. Although attempts have been made in several contexts to explore the constraints impeding the implementation of labour-only contracts during hyperinflationary periods and the strategies to accentuate their effective implementation during such perilous environments, these issues remain underexplored in most developing countries, particularly within the Zimbabwean context. Considering the incessant hyperinflation environment that characterised Zimbabwe since 2000, the study seeks to assess (1) the constraints impeding the effective implementation of labour-only contracts, and (2) the strategies to promote effective implementation of labour-only contracts within the Zimbabwean context. Therefore, the paper addressed two key questions namely (1) What are the constraints impeding the effective adoption of labour-only construction contracts in Zimbabwe's hyperinflationary environment and (2) What are the key strategies to be employed to promote effective adoption of labour-only construction contracts in Zimbabwe's hyperinflationary environment. The findings have potential to assist government, private sector clients and contractors regarding develop mechanisms to effectively implement labour-only contracts for effective project delivery in hyperinflationary environments like that being experienced in Zimbabwe.

In the succeeding sections, the paper highlights literature review on hyperinflationary in Zimbabwe, labour-only contracts, constraints impeding the adoption of labour-only contractors and strategies for effective adoption of labour-only contracts in hyperinflationary environments. This is followed by the

methodology used, data presentation and analyses conducted. Thereafter, discussions, conclusions and recommendations were presented.

Literature Review

The Adoption of Labour-only Contracts in Hyperinflationary Environments

Hyperinflation and its impact on the Zimbabwean construction sector

The Zimbabwean construction industry has been plagued by hyperinflation for over two decades (Magaisa & Musundire, 2022). At some point in 2008, inflation reached astronomical level of about 79.6 billion percent (Richardson, 2015). According to Richardson (2015), this contrary to the experiences in New Zealand where inflation is reportedly low. As noted by Moyo and Crafford (2010), the irrational printing of the local currency by the Reserve Bank of Zimbabwe (RBZ) exacerbated the situation as bad money kept on chasing away good money. Consequently, the construction activities in Zimbabwe were disrupted, with most construction projects being halted indefinitely (Moyo and Crafford, 2010; Huchu, 2013; Mark, 2015). Despite the government concerted efforts to dollarise the Zimbabwean economy (Coomer & Gstraunthaler, 2011) and impose import restrictions to promote the local market, the menace recurred in 2017 to current, with debilitating effects in the construction sector (Mhlanga & Ndlovu, 2021). As a result, the incessant inflation causes shortages of resources in Zimbabwe, with dire consequences on construction budgets (Tshili, 2019). Thus, the question on how to combat the effects of hyperinflation continues.

Labour-only construction contracts during hyperinflation

The use of labour only contracts is largely believed to be one of the best options to execute construction projects in an inflationary environment (Awodele et al., 2019; Pandey, Khan & Scholar, 2023). Most developing countries have adopted labour only contracts to mitigate risks associated with supply and fix contracts during hyperinflation periods (Akinkunmi, Aghimien & Awodele, 2018). By adopting labour only contracts, Akinkunmi, Aghimien & Awodele (2018) posit that the volatility of material prices which is a bane to most contractors during hyperinflation is transferred to the client. Considering the assertion by Ebekozi et al. (2024) that material cost constitutes about seventy-four (74) percent of the total building cost, labour only contracts would undoubtedly reduce risks on the contractors. Additionally, Awodele et al. (2019) claim that this form of procurement would promote engagement of qualified workforce, timely completion of projects and quality enhancement since the contractor will be solely concerned about construction risks. This notion is corroborated by Carvalho, Rafael & Marques (2018) who echoed that the erosion of profitability which is attributed to unprecedented material cost escalations has prompted most contractors in developing countries to view labour-only contracts as more profitable. For instance, Jayathilaka, Waidyasekara & Sirimewan (2021) confirm countries like Nigeria which are sporadically marred by inflationary pressures often employ labour-only contracts to survive the harsh economic environment.

Constraints associated with labour-only construction contracts in a hyper-inflationary environment

There are several factors that affect labour-only contracts in a hyperinflationary environment. It is noteworthy to mention that the success of contractors lies in their ability to manage project costs related to materials, plant, and labour resources (Chigara & Moyo, 2014). However, hyperinflation leads to difficulties in project funding issues, cancellation of contracts, and contractor defaults (Huchu, 2013). According to Huchu (2013), there are high chances of increased vandalism and theft on site due to disgruntled labour onsite leading to high level of materials wastage. Periods of hyperinflation are associated with shortages of major construction materials as local manufacturers reduce production of construction materials to curb high production costs (Moyo & Crafford, 2010). Consequently, most projects are abandoned, delayed or suspended, with some employees having to be unpaid pending resumption of work on site or permanently retrenched (Kumari, Singhal, Majumder, 2021). Thus, it is daunting for trade unions to negotiate wages based on the cost of living during hyperinflationary periods (Bryson & White, 2016). As result, motivating construction employees in the face of hyperinflation is challenging due to the deterioration of their standard of living (Bryson & White, 2016; McIndoe-Calder, 2019). Notably, demotivated employees usually perform poorly, resulting in massive remedial works (McIndoe-Calder, 2019). Generally, hyperinflation intrigues high staff turnover as skilled labour searches for better opportunities elsewhere (Ndlovu & Mukuze, 2023; Bryson & White, 2016; Dhyne

& Mahy, 2012). Extant literature further confirm that hyperinflation makes it difficult for contractors to provide adequate insurance covers (McIndoe-Calder, 2019), maintain the value of retention monies and obtain reliable cost information (Awodele et al., 2019). The cost of late delivery of construction materials due to materials shortages have made the construction industry lose substantial amounts (Moyo & Crafford, 2010). Additionally, reliable contractors are not willing to participate in labour only contracts especially during hyperinflation as the margin of contractor's little profit is reduced due to eroded value of money (Awodele et al., 2019). The identified constraints are summarised on table 1.

Table 1: Constraints associated with adoption of labour only contracts during hyperinflation

Constraint	Source
Late delivery of construction materials	Awodele et al. (2019), Moyo & Crafford (2010)
Longer construction periods	Awodele et al. (2019)
Reduced contractor's profit	Awodele et al. (2019)
Loss of value of retention monies	McIndoe-Calder (2019)
Brain drain / emigration of labour	Bryson and White, (2016)
High project costs due to extension of times	Awodele et al. (2019)
Increased chances of vandalism/theft	Huchu (2013),
Skyrocketing labour costs	Ndhlovu & Mukuze (2023)
High staff turnover/Skilled labour shortages	Bryson and White (2016)
High level of materials wastage due	Bryson and White (2016)
Repetitive work	McIndoe-Calder (2019)
Higher insurance	McIndoe-Calder (2019)

Therefore, table 1 highlights the constraints impeding the effective adoption of labour only construction contractors in hyperinflationary environments.

Strategies for effective adoption of labour-only contracts in hyperinflation environments

Minimising the 'opportunity cost' of resources is important (Mark, 2015). Since contractors struggle to fund and complete projects during hyperinflation, it is therefore necessary that project owners intervene. The labour-only procurement approach, in a challenging economy, can serve as a surviving strategy for construction contractors as it offers cost savings, ensures constant jobs, reduces contractor risk, and maintains contractor's healthy cash flow (Awodele et al., 2019; Akinkunmi, Aghimien & Awodele, 2018). Several studies highlight numerous strategies to successfully implement labour-only contracts which include subcontracting to smaller construction companies; employing workers on production output remuneration basis as opposed to hourly rates, use of modern construction methods that minimise waste, payment of contractors in stable currencies, offering incentives to retain skilled labour, agreeing with clients to hybrid payment methods where part payments are made in kind, or forex and local currency (Hendrickson, Carl & Tung, 2024; Johnson & Babu, 2020; Awodele et al., 2019; Akinkunmi, Aghimien & Awodele, 2018).

Research Methodology and Method

The study adopted a quantitative approach, which employed a cross-sectional questionnaire survey tool to gather data on the level of adoption of labour-only contracts from contractors and registered quantity surveying professionals, engineers, architects, and project managers in Zimbabwe. This was done to understand views and perceptions from different professionals who are involved in contract management in the industry. Cost control is not the sole responsibility of a quantity surveyor, but it is teamwork amongst the project officials (Wao & Flood, 2016). A quantitative approach enabled objective evaluation and generalizability of the results (Leavy, 2017). The approach is corroborated by Awodele et al. (2019) who used a cross-sectional survey design on a similar study. The questionnaire survey was administered online to allow the collection of a large amount of data as alluded to by Almalki (2016). Simple random sampling technique was used, each member of the two hundred and fifty-one targeted population had an opportunity to be involved in the survey (Saunders, Lewis & Thornhill, 2019). The questionnaire survey comprised three (3) sections. Section A for the respondents' demographics, Section B sought to establish the constraints impeding the successful acceptance of labour-only construction agreements in the Zimbabwean industry. Each constraint was rated using a 5-point Likert

scale where 1 = not severe, 2=slightly severe, 3= moderate, 4= severe, 5= very severe. Then, Section C sought to determine strategies to promote effective adoption of labour-only construction contracts in a hyperinflationary environment of Zimbabwe. Respondents were also asked to rate the level of importance or relevance of each of the strategies identified in literature using a 5-point Likert scale where 1= unimportant, 2= less important, 3= moderate, 4= important, 5= very important. Python Package and Microsoft excel were used for computing the collected data as well as generating a data base of responses (Puteh & Azman, 2017). The data was analysed through the computation of mean scores (MSs) and their ranking. The range of interpreting the 5-point Likert scale mean score for objective 1 which relates to the constraints impeding the effective adoption of labour-only contracts was given as follows: MSs>1.00 ≤ 1.79 (Very mild), MSs>1.80 ≤ 2.59 (mild), MSs>2.60 ≤ 3.39 (Moderate), MSs>3.40 ≤ 4.19 (severe) and MSs>4.20 ≤ 5.00 (Very severe), while for objective 2 which relates to the strategies for the effective adoption of labour-only contracts was given as follows: MSs>1.00 ≤ 1.79 (Unimportant), MSs>1.80 ≤ 2.59 (Less important), MSs>2.60 ≤ 3.39 (Moderate), MSs>3.40 ≤ 4.19 (Important) and MSs>4.20 ≤ 5.00 (Very important).

To ensure questionnaire validation, a pilot study with five questionnaires was carried out for pre-testing the research questions to measure their relevance and clarity such that they become compatible for measuring variables under study and improve its quality (Moser & Kalton, 1979). The questionnaire was then edited on the issues raised from the pilot questionnaire. These included a correction on the Likert question about resources challenges as well as the question about percentage of labour only contracts executed which was added. The Statistical Python package and excel package was used to accurately calculate the findings

Table 2: Sampling frame

Respondents	Harare & Bulawayo target Population	Targeted sample size $n = N/(1+N(e)^2)$
Contractors Category A and B	99	51
Quantity Surveying firms	19	10
Engineering Firms	67	35
Architects Firms	66	34
TOTAL RESPONDENTS	251	130

The above table shows the population as well as the sample size obtained calculated using Yamane's formula. Most professionals in Zimbabwe are operating from contractors followed by Engineering and Architect firms and lastly the Quantity Surveyors. More than 65% of the population is operating from Harare and Bulawayo provinces, making these provinces a true representation of the Zimbabwean construction industry.

Research Results

Response rate

Ninety-nine valid responses were received, thus constituting a response rate of 76.15%. The response rate aligns with findings from a previous study by Moser and Kalton (1979) who argue that survey results could be biased and of limited value if the return rate fell below 30%-40%). In support, Tshili (2019) indicated that for consideration and commentary, response rate of 50% is acceptable, 60% is great and the one above 70% is outstanding reliability and validity of data.

Demographics of respondents

Table 3: Respondents' profile

Variable	Responses	Response Percentages
Qualification		
Project Managers	20	20.2%
Architects	22	22.2%
Quantity Surveyors	31	31.3%
Engineers	26	26.3%
TOTAL	99	100%
Highest level of academic education		
PHD	0	0%
Master's degree	41	41.41%
Bachelor's Degree	50	50.51%
Diploma	8	8.08%
Certificate	0	0%
TOTAL	99	100%
Years of experience in the construction industry		
More than 20 years	9	9.09%
16 – 20 years	44	44.44%
11 - 15 years	29	29.30%
6 – 10 years	10	10.1%
0 - 5 years	7	7.07%
TOTAL	99	100%
Category of company in the construction industry		
Contractor	41	41.4%
Architect firms	22	22.2%
Quantity Surveyors firms	10	10.1%
Engineering firms	26	26.3%
TOTAL	99	100%
Professionals involved in management of a labour only contract		
YES	89	90%
NO	10	10%
TOTAL	99	100%

Twenty were in project management, 26 were in engineering, 22 were in architecture, and 31 were in quantity surveying, according to the study. The majority of project officials had a master's degree (51%), (41%) had a degree whilst 8% had a diploma. Neither a certificate alone nor a PhD was held by any of the responders. This suggests that the participants possessed the necessary educational background to comprehend and react suitably to the survey questions. In addition, the majority of research participants had 16 to 20 years of overall job experience, scoring a 44 (44.44). Given that 92.93% of the respondents have worked in the business for more than five years overall, it can be assumed that the data was accurate. Over 70% of the participants reported having experienced working during hyperinflation in Zimbabwe. Though less than 10% of the respondents had never worked on a labor-only construction project, contractors should prefer labor-only contracts over supply and fix contracts during hyperinflation (Awodele et al., 2019). Of the 85.39% people who once worked on labor-only contracts, projects done under labour only contacts constitute only less than 20% of all projects undertaken, indicating that the adoption of labor-only contracts is still very low in the Zimbabwean construction industry (Nyoni & Bonga, 2016).

Constraints faced in implementing labour-only agreements during a hyperinflation

The study asked respondents to rate the severity of constraints identified in literature in the implementation of construction projects during a hyperinflation period in Zimbabwe, using a 5-point likert scale where 1 = very mild, 2=mild, 3= moderate, 4= severe, 5= very severe. The range of interpreting the 5-point Likert scale mean scores was given as follows: MSs>1.00 ≤ 1.79 (Very mild), MSs>1.80 ≤ 2.59 (mild), MSs>2.60 ≤ 3.39 (Moderate), MSs>3.40 ≤ 4.19 (severe) and MSs>4.20 ≤ 5.00 (Very severe). Table 3 below shows the results of the study.

Table 4: Constraints faced in the implementation of construction projects

Challenge	N	Mean score	Rank
Prolonged construction periods	99	4.10	1
Decreased contractor's margin of profit	99	4.03	2
Loss of value of retention monies	99	3.91	3
Labor emigration or brain drain	99	3.89	4
Hefty project expenses because of schedule extensions	99	3.87	5
Greater likelihood of theft or vandalism	99	3.61	6
Ever increasing labour costs	99	3.59	7
Scarcity of proficient workers	99	3.30	8
Excessive waste rate of materials	99	3.30	9
Repetitive work	99	3.15	10
An increase in insurance charges owing to hyperinflation	99	2.40	11
Unsatisfactory insurance policy terms	99	2.10	12
Valid N (Listwise)	99		

The findings of the study show that delivering of construction materials late (4.13) and prolonged construction periods (4.10) are very severe on construction projects in a hyperinflationary environment like Zimbabwe. Additionally, the respondents noted that decreased contractor's margin of profit (4.03), loss of value of retention monies (3.91), labour emigration or brain drain (3.89), hefty project expenses as a result of schedule extensions (3.87), greater likelihood of theft or vandalism (3.61) and ever-increasing labour costs labour prices (3.59) are severe within the Zimbabwean context. All the mentioned constraints which range from severe to very severe are regarded as prevalent and deleterious during hyperinflation periods. In a nutshell, the results show that material and labour costs are volatile which complicates budgeting and planning. Also, erosion of profits poses huge financial strains on projects. However, most respondents perceived those constraints like skilled labour shortages (3.30), huge material wastage (3.30), repetitive work (3.15) and high insurance costs (2.40) were moderate to mild during hyperinflation periods since their ratings fall either within $MSs > 1.80 \leq 2.59$ (mild) or $MSs > 2.60 \leq 3.39$ (Moderate).

Strategies used to promote effective implementation labour-only contracts in hyperinflationary environment

To probe the strategies used to promote effective implementation of labour-only contracts, the study asked the respondents to rate the importance of each of the strategies identified in literature to enhance effective implementation of labour-only contracts in Zimbabwe. The respondents rated using a 5-point likert scale where 1= unimportant, 2= less important, 3= moderate, 4= important, 5= very important. Data was interpreted based on the following mean interpretation range: $MSs > 1.00 \leq 1.79$ (Unimportant), $MSs > 1.80 \leq 2.59$ (Less important), $MSs > 2.60 \leq 3.39$ (Moderate), $MSs > 3.40 \leq 4.19$ (Important) and $MSs > 4.20 \leq 5.00$ (Very important). Table 3 below shows the results of the study.

Table 5: Strategies for enhancing implementation of contracts limited to labour only

Techniques for putting into practice labor-only contracts successfully	N	Mean Score	Rank
Subcontracting to smaller construction companies	99	4.04	1
Employee compensation will be based on production output rather than hourly wages	99	4.00	2
Settling on hybrid payment arrangements with clients	99	3.84	3
Employee development and training for successful project management	99	3.72	4
Provide incentives to retain skilled workers	99	3.63	5
Payment of contractors in stable currencies	99	3.61	6
Hiring employees under NEC in situations where hourly salary rates are used for payment	99	3.50	7
Utilising contemporary building techniques to reduce waste	99	3.10	8
Valid N (Listwise)	99		

From Table 4, the results reveal that most stakeholders viewed subcontracting work to small construction companies (4.04) and production output-based remuneration (4.00) to very important strategies to effectively implement labour-only contracts during hyperinflationary periods. In addition, strategies which were considered important include settling on hybrid payment arrangements with clients when there are many payment methods used, such as local currency, forex, or in kind (3.84), employee development and training for successful project management (3.72), offer incentives to keep skilled labour (3.63), payment of contractors in stable currencies (3.61) and employing workers under NEC where payments are made on hourly wage rates (3.50). However, strategy was viewed as moderately important is the use of modern construction methods to minimise wastage with a mean score of 3.10. Although the ratings demonstrate that the importance of the mentioned strategies varies, the findings show that most of the strategies listed in Table 4 fall within $MSs > 3.40 \leq 4.19$ to $MSs > 4.20 \leq 5.00$ which implies that they are highly important to stakeholders in the Zimbabwean context to bolster the implementation of labour only contracts.

Table 6: The strategies that are used to successfully implement labour-only contracts in Zimbabwe

Strategies to successfully implement labour-only contracts	P value	Cramer's V values	Ranking
Subcontracting to smaller construction companies	< 0.001	0.337	1
Employing workers under NEC where payments are made on hourly wage rates	< 0.001	0.319	2
Production output to be used for employee remuneration rather than hourly based remuneration.	< 0.001	0.243	3
Use of modern construction methods to minimise wastage	< 0.001	0.236	4
Payment of contractors in stable currencies	< 0.001	0.220	5
Training and development of workers for effective and efficient project management	< 0.001	0.215	6
Offer incentives to keep skilled labour	< 0.001	0.210	7
Agreeing with clients to hybrid payment methods where payments are made in two or more ways including but not limited to in kind, forex or local currency.	< 0.001	0.208	8

Cramer's V is a coefficient that provides a normalised value between 0 and 1, where 0 indicates no association and 1 signifies a perfect relationship (Michael, 2017). The tests measured the significance of the relationships between the labour only contracts and project delivery during hyperinflation in Zimbabwe construction industry.

Discussion

Constraints faced in the implementation of Labour-only contracts during a hyperinflation environment

The findings reveal several constraints characterising a hyperinflationary environment, which are detrimental on the delivery of construction projects. The study noted that the highly detrimental constraints include late delivery of construction materials, longer construction periods, reduced

contractor's profit, loss of value of retention monies, brain drain/emigration of labour, high project cost costs due to extension of time, increased chances of vandalism/theft and skyrocketing labour prices. These findings are consistent with existing literature. For instance, Chigara and Moyo (2014) posit that the success of contractors lies in their ability to manage project costs related to materials, plant, and labour resources. However, resource management is reportedly daunting in a hyperinflation environment due to difficulties in project funding issues, cancellation of contracts, and contractor defaults (Kumari *et al.*, 2021). Also, shortage of major construction materials is rampant during hyperinflation periods as local manufacturers would reduce production of construction materials to manage skyrocketing production costs (Moyo & Crafford, 2010). On the other hand, some studies argue that there are high chances of increased vandalism and theft on site due to disgruntled labour onsite leading to high level of materials wastage (Huchu, 2013). As noted by Carvalho *et al.* (2018), these constraints experienced in hyperinflationary environments lead to noncompletion of construction projects and demotivation of employees as alluded to by Bryson and White (2016). To elaborate, Bryson and White, (2016) express the difficulty of negotiating wages during hyperinflation due to volatility of prices. Moreover, Dhyne and Mahy (2012) contend that unprecedented brain-drain often surface due to unfair remuneration thereby stifling the successful delivery of projects. Additionally, providing adequate financing and insurance for projects during a hyperinflationary period is difficult (McIndoe-Calder, 2019). Therefore, the results show that the Zimbabwean context encounters a myriad of constraints which require apt strategies to enhance effective project delivery, considering the ineffectiveness of commonly the employed labour-only contracts.

Strategies used to promote effective implementation labour-only contracts in hyperinflationary environment

To enhance the implementation of labour-only contracts for effective delivery of projects in a hyperinflationary environment, the findings reveal the importance of several strategies to be employed by stakeholders in the Zimbabwean context. These include subcontracting to smaller construction companies, use of production output-based remuneration system as opposed to hourly based remuneration, agreeing with clients to hybrid payment methods where payments are made in two or more ways including but not limited to in kind, forex or local currency, training and development of workers for effective and efficient project management, offering incentives to keep skilled labour, payment of contractors in stable currencies. The results are supported by most literature. For instance, Akinkunmi, Aghimien & Awodele (2018) argue that subcontracting is the best strategy to deal with increased costs during hyperinflation since this would accelerate the construction process as well as sharing risks. Furthermore, the introduction of multi-currency system in Zimbabwe enabled contractors to be paid in foreign currency, hence improved the implementation of labour only contracts as well as the successful delivery of projects. Notably, by paying contractors with stable currency, contractors easily adjust to the fluctuating prices by adjusting employee wages accordingly. This is corroborated by Magaisa & Musundire (2022) who highlight that employees who are paid with a stable currency are motivated to be productive and consequently improve their performance.

The strategy that was rated the least effective in addressing the negative effects of hyperinflation was employing workers under NEC where payments are made on hourly wage rates (Bajari, Stephanie & Steven, 2014). This was the most used strategy as it allows contractors to pay workers close to nothing for work done. This is because employees will be disgruntled and that will contribute more to the challenges of the effects of hyperinflation. Huchu (2013) agreed that employees will be discontented during hyperinflation because the disposable income available for workers to adequately meet their daily needs will be slim to none, consequently causing disgruntlement that manifests in the wastage of project materials by workers as unproduction on site. On the other hand, the Cramer's V result of 0.257 indicated the moderate Cramer's V value suggesting a considerable variation in the ratings for different aspects of labour-only contracts (Kearney, 2017). This indicates diverse perceptions among respondents, with some aspects being more critically or favourably viewed than others.

Conclusion

The main objective of the study was to assess the adoption of labour-only construction contracts to enhance project delivery in Zimbabwe's hyperinflationary economy. Analysis of data showed that there is low rate of use of labour only contracts during the hyperinflation in Zimbabwe as hyperinflation remains deleterious to the effective delivery of construction projects as highlighted by Awodele *et al.* (2019). The strategies to improve the adoption of labour only contracts during hyperinflation were

highlighted which showed that labour only can indeed improve project delivery during hyperinflation. This was supported by Awodele et al. (2019). The current study therefore sought to identify the impediments of the effective adoption of labour-only contracts and then assess the strategies to promote the effective implementation of labour-only contracts for successfully project delivery in a hyperinflation in Zimbabwe. Based on the findings of the study, hyperinflation causes numerous constraints that impede the effective adoption of labour-only contracts in Zimbabwe which include late delivery of construction materials, longer construction periods, reduced contractor's profit, loss of value of retention monies, brain drain/emigration of labour, high project cost costs due to extension of time, increased chances of vandalism/theft and skyrocketing labour prices. In view of these constraints characterising a hyperinflation environment, the study concludes that stakeholders should employ five key strategies that were viewed by respondents as important to improve the adoption of labour-only contracts (Johnson & Babu, 2020). It is imperative that work be subcontracted to smaller construction companies to accelerate the construction process and share risks; that production output-based remuneration system be used instead of hourly based remuneration to reduce costs; that clients agree to hybrid payment methods in which payments are made in both local currency; and those incentives be provided in order to retain skilled labor. These five strategies should be supplemented by a dynamic procurement team that expedites planning and decision-making; additionally, stakeholders should utilise an appropriate standard form of contracts that allows flexibility during a hyperinflation environment to enhance effective project delivery (Huchu, 2013).

Therefore, the findings could assist both contractors and clients to develop appropriate procurement methods or strategies to enhance effective project delivery during a hyperinflation environment like the Zimbabwean context. While the results of the study provide invaluable insights, the sample size and contextual differences preclude the findings from being generalised to other contexts without caution.

Recommendations

Because hyperinflation has become a key feature of the Zimbabwean economy, the study suggests implementing the identified tactics for effective labour-only contracts to improve project delivery in this setting. To improve cost management, Quantity Surveyors must take the initiative in educating customers and investors about the possible benefits of labour-only contracts during hyperinflation. A contract management structure must be established and monitored in order to ensure efficient project delivery amid hyperinflations. To expedite the implementation of National Development Strategy 1 on home development, it is recommended that labour-only contracts be enforced. The report suggests that to improve labor-only contract implementation, organisations that oversee the construction sector, such as the Construction Industry Federation, should organise and sponsor training sessions or workshops.

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Assessing the Critical Causes of Construction Contracts Misinterpretation Among Small and Medium Enterprise Contractors

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Abstract

The research paper aims to explore the causes of contract misinterpretation by small and medium enterprise (SME) contractors and to identify the construction contracts most likely to have readability difficulties. An online survey was conducted based on the readability of construction contracts and the causes thereof on SME contractors. The target population for this study was SME contractors residing in Gqeberha, Eastern Cape Province, South Africa. Descriptive statistics were used to determine the common causes of misinterpretation of construction contracts. In addition, the level of knowledge, experience, and interpretation SME contractors have when it comes to construction contracts used in South Africa was investigated. The results showed that the use of complex words, the same word in clauses with different meanings, and the lack of training in construction contracts were critical causes of misinterpretation. The results further indicated that the JBCC PBA, the most frequently used construction contract, required remedial action to enhance interpretation. The low responses were a limitation, however, the exploratory nature of the study supports the validity of the initial findings. Contract misinterpretation is one of the main causes that can lead to disputes on construction projects. Awareness of contract training must be raised among SMEs. Construction contracts must be written in simple terms, with less cross-references and complex sentence structuring, to increase contract readability and reduce misinterpretations leading to disputes. The results of this paper indicated that Eastern Cape SME contractors likely face constraints on their projects due to their failure to interpret and comprehend clauses in construction contracts. This emphasises the need for contract training among SMEs.

Keywords: Standard forms of Contract, Small and Medium Enterprises, Readability, Construction Industry, Misinterpretation.

Introduction

Othman & Harinarain, 2009: 83 stated that “Construction is a complex and risky business. It is a time-consuming process involving a multitude of organisations with different objectives and skills”. Tayeh et al., (2020) states that construction risks can either be avoided, reduced, transferred, or absorbed. Dulu (2019) explains that construction contracts are used to convey the intentions of the parties involved and how the project risk will be shared amongst the stakeholders. Othman and Harinarain (2009) further argue that construction projects have different complexities, but they are all exposed to risk and can go wrong. This is why it is of paramount to have contracts that are understood by all parties

Construction contracts contain the rights and obligations of the contracting parties, the specifications and costs associated with construction. These aspects are critical to project success as Haupt and Dulu (2016) argue that lack of understanding of the terms and conditions of contract documents can lead to disputes which further leads to project delays, increased project costs and damaged business relationships. The risk associated with the lack of understanding of contracts has led to the development of standard forms of contract, and as Rameezdeen and Rodrigo (2014) state standard forms of contracts were developed by professional bodies and government organisations with the intention to equally share the project risks among the stakeholders.

Over the years, users found standard forms of contracts difficult due to complex legal language and have been criticised for being difficult to read and understand (Rameezdeen & Rodrigo, 2014). This complexity can prove to be a challenge for small and medium enterprise (SME) contractors as Adendorff, Appels and Botha (2011) highlight that small and medium-sized enterprises (SMEs) in South Africa are prone to fail within the first five years of being in business.

Complex contracts mean that SME contractors are likely to misinterpret contract conditions, and if there is a lack of comprehension and understanding of the contract, project failure is inevitable (Haupt & Dulu, 2016). Rameezdeen and Rodrigo (2014) state that plainly written text is crucial in the understanding of construction contracts and reduces disputes on site, and this is important for SME contractors, as SMEs play a significant role in project success, and on a broader scale the growth and development of the economy (Adendorff, Appels & Botha, 2011). According to Chong and Zin (2010), misinterpretation of construction contract clauses is one of the leading causes of construction disputes, and there has been an urgent need for the parties involved to understand the contract clauses and agree on their meaning to be clear on their rights and obligations.

The objectives of the study were to examine which construction contract used in the South African construction industry is likely to have readability issues, to determine which construction contract is likely to experience disputes as result of these readability issues, and to explore the critical contracts' misinterpretation among SME contractors.

Literature Review

The construction industry is one of the main economic driving forces of South Africa (Hove, 2015). Investing in infrastructure creates significant employment opportunities that generate further investment in other sectors and investing in infrastructure creates a multiplier effect that stimulates the economy (Dlamini, 2012). Former president Zuma (2015) stated during the State of the Nation Address that 30 per cent of certain state procurements would be reserved for small business. Rob Davies, the Minister of Trade and Industry (Davies, 2015), also stated that the objective is to "...institutionalise a 70 per cent procurement target for emerging businesses". Incorporating SMMEs successfully into the construction industry is thus of great importance for the economy of South Africa.

Researchers estimate that SMME enterprises make up 91 per cent of formalised businesses in South Africa and furthermore provide approximately 60 per cent of the total labour force. SMMEs account for 34 per cent of GDP (How do small businesses influence the South African economy, nd). Gasa (2012) states that continuous learning of SMMEs adds to the growth of individual staff members as well as the organisation. The disadvantage of such programmes is that SMMEs become comfortable within this protective environment, inhibiting the urge to graduate and therefore reducing opportunities for upcoming graduates (Gasa, 2012). Fundamental to understanding the current SMME dynamics in the construction sector is understanding the role that the construction sector is meant to play in economic development. Development of SMMEs is crucial for professionalising the industry and seeing SMMEs moving upwards from low CIDB gradings (South African Cities Network, 2023: 8, 25).

According to Ademola (2012), many SMMEs have little to no financial knowledge on how to manage a construction project. This statement was supported by Gasa (2012) who suggested that most SMMEs cannot manage their finances adequately. This leads to mismanaged funds and in many cases abandonment of the project, often resulting in the appointment of another contractor to take the project to completion.

Types of standard forms of contracts used in South Africa

Construction is a complicated process with activities operating concurrently, and at times interacting with one another to achieve the goal of completion within the specified time, budget, and quality (Othman & Harinarain 2009). Standard forms of contracts were developed with the goal of assisting with the communication of the rights and obligations of the contractor, client, and other stakeholders, to avoid any conflicts or confusion (Rameezdeen & Rodrigo 2013). These contracts are drafted to control, coordinate and adapt to risks associated with construction projects (Chen, Wang, Zhang & You, 2018). In South Africa, there are currently 4 types of standard forms of contracts that are in use in the industry, and this includes the FIDIC (French acronym for International Federation of Consulting Engineers)

1999, General Conditions of Contracts for Construction Works (GCC 2004), NEC3 family of standard contracts, and Joint Building Construction Committee (JBCC) (CIDB, 2005).

FIDIC (French acronym for International Federation of Consulting Engineers)

Established in 1913, the FIDIC comprises four (4) forms of contracts with an array of uses, this includes conditions of contracts for construction (the 'Red book'), conditions of contract for plant and design-build (the 'Yellow book'), Turnkey projects conditions of contract (the 'Silver book') and short form of contract (the 'Green book') (CIDB 2005). One of the main objectives behind the creation of these contracts was to simplify the language that has been used, thereby minimising disputes. For this, the FIDIC suite of contracts is the most widely used international form of construction contract in the world (Bayomi & Eldosouky, 2022; Besaiso et al., 2018).

New Engineering Contract (NEC 3) family of standard contracts

Established in 1985 by the Council for the London Institute of Civil Engineers, the NEC 3 is used for both construction and engineering projects. (CIDB, 2005). The NEC 3 has started to become popular over the years as its project success rate has increased because of projects being completed on time and within budget (Javed et al., 2020). Javed et al, (2020) explain that the NEC enhances collaboration and project success. The author explains that the NEC does this through flexibility and having early warning systems for risk and change management. Furthermore, NEC often achieves project success because it boasts three key elements, which are, clarity and simplicity of text, flexibility and stimulus to good management (Javed et al., 2020).

General Conditions of Contracts for Construction Works (GCC 2010)

Developed by the South African Institution of Civil Engineering, the GCC 2010 has been published countless times to address the issues of misunderstanding of responsibilities and to provide for a wider range of construction works (Claassen, 2010). Claassen (2010) states that the GCC 2010 has conditions that are clearer than those found in international forms of contracts. SAICE (2010) explains that the GCC 2010 has been amended to make it simplified, this has resulted in some clauses that have the same meaning being grouped for better comprehension and new regulations on health and safety and environmental impact, and conditions on programme of works, performance guarantee, dispute resolution have all been updated with the latest thinking.

Joint Building Contracts Committee (JBCC PBA)

Established in 1984, the JBCC is made up of six (6) member organisations that constitute the South African build environment these member organisations include the Association of South African Quantity Surveyors, the South African Institute of Architects, the South African Association of Consulting Engineers, the South African Property Owners' Association, the Specialist Engineering Contractors Committee, and the Building Industries Federation of South Africa (Othman & Harinarain, 2009). Othman and Harinarain (2009) explain that the JBCC contracts are known for their clarity and transparency, which assist the parties involved to understand their obligations and rights, the standardised language of JBCC PBA also helps reduce disputes as parties clearly understand their rights and obligations.

Factors inhibiting the understanding of standard forms of contracts

Chong and Zin (2010) state that a lack of understanding of contracts is one of the main causes of disputes on site. The need for clearly written contracts is the reason standard forms of contracts were developed and are continuing to be updated (CIDB, 2005). Literature reveals that there are numerous causes that inhibit the understanding of standard forms of construction contracts and only nine have been included which are the use of complex words, the use of the same word in clauses that have different meanings, no training in construction contracts, multiple cross-referencing, inexperienced contractor, clauses that use legal terms/ language, the use of passive (Indirect) sentences, long and repetitive clauses, and clauses not written in own native language.

Ballesteros-Lintao and Ameer Ali (2022) explain that standard forms of contracts tend to use complex words as these contracts are often drafted by committees who are not parties to these contracts. The

authors argue that this tends to decrease clause readability, thereby increasing misinterpretation of the clauses.

Causes of misinterpretation of contracts

Construction contracts are written agreements signed by the contracting parties to define their relationships and obligations (Chong & Zin, 2010). Construction contracts are legally binding documents, usually entered by the contractor and client. These contracts are then administered by construction professionals such as Quantity surveyors, architects, engineers, or project managers (Ballesteros-Lintao & Ali, 2022). In as much as these contracts are managed by professionals, the breach of contract mostly affects the client and the contractor, hence it is imperative for these contracts to be well-written to avoid any conflicts from arising and to have successful project outcomes (Rameezdeen & Rodrigo, 2013).

Well-written contracts are crucial to project success because it becomes easy for the parties involved to manage risk during the implementation phase, it lowers the cost of wastage in construction works and lessens opportunistic behaviour between the client and the contractor (Ballesteros-Lintao & Ameer Ali, 2022). Contrary to this, contracts are written in a legal language that is not written in the standard English language and tend to break grammar rules, which makes it difficult for the untrained individual to read and interpret (Finnegan, 2018). The conditions of the contract are crucial to ensure that the parties abide by the rules and regulations. Poor understanding may lead to construction disputes, as highlighted by Chong and Zin (2010).

Elkhayat and Marzouk (2022) highlight that having a clear, simple, and flexible construction contract is an almost impossible task and these are the three components that determine a contract's readability. Gopal et al., (2021) explain that readability is the examination of the complexity of words and sentence structure and can be assessed using readability formulas. Rameezdeen and Rajapaske (2007) argue that when the readability of a clause is low, the chances of different readers coming up with different interpretations are high, hence readability is concerned with the interpretability of words and sentences.

Literature reveals that numerous causes inhibit the understanding of standard forms of construction contracts, and only nine have been included in this research, and they are listed below (Oshungade & Kruger, 2017; Dubai, 2004; Ali & Wilkinson, 2010; Ballesteros-Lintao & Ameer Ali, 2022; Rameezdeen & Rodrigo, 2013):

- The use of complex words.
- The use of the same word in clauses that have different meanings.
- No training in construction contracts.
- Multiple cross-referencing.
- Inexperienced contractor.
- Clauses that use legal terms/ language.
- The use of passive (Indirect) sentences.
- Long and repetitive clauses.
- Clauses not written in their native language.

Ballesteros-Lintao and Ali (2022) explain that standard forms of contracts tend to use complex words as these contracts are often drafted by committees who are not parties to these contracts. The authors argue that this decreases clause readability, thereby increasing misinterpretation. Ali and Wilkinson (2010) advocate using plain language to reduce legibility caused by using complex words in contracts. Ballesteros-Lintao and Ali (2022) reinforced this statement by explaining that construction contracts can be more effective if designed and written in plain legal language. According to a study by Akal (2022), a lack of clarity in contracts can be attributed to sentences that are too long, redundant legal expressions, poor layout and too many cross references. Oshungade and Kruger (2017) explain that based on their analysis from contractors and clients, they identified contractual relationship-related factors as the most common causes of delays and disruptions among the client and contractor.

Research Methodology

The research was conducted using the positivist paradigm with a deductive approach similar to a study conducted by Kampman (2018). The research was structured and used a scientific method to determine

the relationship between observable and measurable facts objectively. Therefore, the epistemological assumptions of this research are based on empirical knowledge, and the ontological assumptions are based on objectivism (Saunders et al., 2016). Due to the time constraints of this study, the cross-sectional time horizon was employed. An exploratory research approach was adopted using an online questionnaire survey instrument based on a five-point Likert scale. Based on a quantitative research approach, the questionnaire was distributed to 25 selected SME, in grade 1 to 4 of the CIDB, contractors in Gqeberha, South Africa. Six (6) contractors responded representing a response rate of 24%. Descriptive statistical methods such as the mean and standard deviation were used to analyse the data.

The mean was interpreted as follows:

- $>4.20 \leq 5.00$ (Strongly agree) (Excellent)
- $>3.40 \leq 4.20$ (Agree) (Good)
- $>2.60 \leq 3.40$ (Neutral) (Average)
- $>1.80 \leq 2.60$ (Disagree) (Poor)
- $>1.00 \leq 1.80$ (Strongly disagree) (Very poor)

Normalisation was undertaken, to the interval (0,1), and considered critical causes of misinterpretation at $NV \geq 0.50$ (Omer et al., 2022).; where:

$$NV = \frac{(\text{Mean value} - \text{Minimum mean})}{(\text{Maximum mean} - \text{Minimum mean})}$$

Results and Findings

The results and discussion section considered the response rate, profile of respondents, critical causes of misinterpretation and Table 1 indicates the demographics of the participants.

Table 1: Demographics			
Gender			
Male	87.5%	Female	12.5%
Qualification			
Diploma	25.0%	Honours	25%
Bachelor	37.5%	Masters	12.5%
Experience			
3-5 years	12.5%	11-15 years	12.5%
6-10 years	62.5%	16-20 years	12.5%

From Table 1, majority of participants were males. Majority (75%) of participants have at least a Bachelor's degree. More than half (62,5%) of respondents have 6 to 10 years of industry experience. All the participants are from SMEs contractors in grade 1 to 4 of the CIDB membership list.

Table 2 depicts the causes of contract misinterpretation. These are ranked according to the respondent's perceived likelihood of each cause leading to misinterpretation using the mean value.

Table 2: Causes of misinterpretation

Rank	Causes of contract misinterpretation	Mean	SD	NV
1	The use of complex words	4,00	1.20	1.00*
2	The use of the same word in clauses that have different meanings	3,89	1.05	0.89*
3	No training in construction contracts	3,89	1.36	0.89*
4	Multiple cross-referencing	3,44	1.33	0.44
5	Inexperienced contractor	3,44	1.33	0.44
6	Clauses that use legal terms/ language	3,38	1.85	0.38
7	The use of passive (Indirect) sentences	3,33	0.82	0.33
8	Long and repetitive clauses	3,11	1.45	0.11
9	Clauses not written in own native language	3,00	1.69	0.00

NV- Normalisation value, *- Critical causes of misinterpretation

Table 2 indicates that five from the nine causes of contract misinterpretation identified were agreed with ($>3.40 \leq 4.20$). The main cause of misinterpretation that were identified were the use of complex words ($MS=4.00$), followed by no training in construction contracts ($MS=3.89$), the use of the same word in clauses ($MS=3.89$), multiple cross-referencing ($MS=3.44$), and inexperienced contractor ($MS=3.44$). The remaining four causes of misinterpretation which were neutral ($>2.60 \leq 3.40$) are clauses that use legal terms of language ($MS=3.38$), followed by using passive (indirect) sentences ($MS=3.33$), and long and repetitive clauses ($MS=3.11$). Clauses not written in own native language were identified at the least cause of contract misinterpretation ($MS=3.00$).

The normalisation value (NV) test indicates that the use of complex words, no training in construction contracts and the use of the same word in clauses with different meanings, are identified as the three critical causes of misinterpretation.

These three critical factors are discussed hereafter. The use of complex words, as supported by Oshungade and Kruger (2017), must be limited. It must be generally understood that construction contracts are operationalised by contractors of various knowledge levels. In addition, since the registration of construction companies is not dependent on the accrual of construction knowledge, then construction contracts must be simplified for the benefit of every participant in the South African construction industry. Ambiguity of phrases is also concerning among SME contractors, as alluded by Ballesteros-Lintao and Ali (2022). The simplest of languages must be used to reduce any ambiguity and expose the accurate meanings of clauses. It is not surprising that SME contractors have indicated that they have no training in construction contracts. As supported by Finnegan (2018), untrained individuals have difficulty in interpreting contracts. However, the solution is not as simple as it sounds. Advancing training in contracts may not remedy the challenge as anticipated. This is due to SME contractors likely having lower knowledge levels. Further analysis may be required to justify the promotion of joint ventures or partnering for SMEs to alleviate this challenge.

Table 3 shows SMEs level of knowledge, experience, level of interpretation of clauses for each of the standard form of contracts commonly used in the South African construction industry.

Table 3: Standard forms of contracts		
Knowledge level		
	Mean	SD
JBCC PBA	3,56	1,42
NEC3	3,00	1,58
GCC	3,00	1,41
FIDIC	2,56	1,33
Level of experience		
JBCC PBA	3,22	1,48
NEC3	2,89	1,17
GCC	2,78	1,09
FIDIC	1,89	0,93
Clause interpretation		
JBCC PBA	3,33	1,12
GCC	3,33	1,32
NEC3	3,13	1,36

FIDIC	2,78	1,30

It is evident from Table 3 that SMEs have good knowledge ($>3.40 \leq 4.20$) of the JBCC PBA and align with the findings by Othman & Harinarain (2009). It is perceived that the JBCC PBA is the most popular contract document used by SMEs. The level of knowledge relating to the other contracts are average to poor. However, for the other standard forms of contracts (NEC3 and GCC), any prior simplification (Claassen, 2010; Javed et al., 2020), has not been supported by SME contractors. Even the popular FIDIC (Sima, 2022) has poor knowledge levels. This finding contradicts the results on the causes of misinterpreting construction contracts in that the level of knowledge is not reflected in the results. It is likely that the participants purport their level of knowledge on other aspects other than interpretability. The level of experience related to the FIDIC contract is poor ($>1.80 \leq 2.60$), while for the other contracts it is average ($>2.60 \leq 3.40$). Clause interpretation for all contracts clauses appears to be average ($>2.60 \leq 3.40$). From the above results it can be deduced that the JBCC PBA is the most frequently used form of contract by SMEs which resulted in good knowledge level of the contract, however, clause interpretation is moderate. The other three standard forms of contract are more concerning as the knowledge level, and clause interpretation is average.

Conclusion and Recommendations

The objectives of this paper were to determine the causes of contract misinterpretation by SME contractors, and to examine which form of construction contracts used are likely to have readability issues. Construction contracts are the tools used to manage this risk by either reducing it, transferring it or absorbing the risk, and contracts are set in place for this specific purpose. Failure to interpret and comprehend contract clauses can lead to project failure. It is therefore imperative to have contract clauses written in a simple understandable language to increase contract comprehension. It is clear from the results that the critical causes for the misinterpretation of construction contracts are the use of complex words, the use of the same word in clauses with different meanings, and the lack of training in construction contracts.

It is recommended that SMEs should undertake training related to construction contracts, to equip them with adequate knowledge of the specific contract details, the implementation thereof, financial consequences, and associated risk. Contract drafters are also encouraged to use simpler text, with less cross referencing of clauses to eliminate ambiguity and misinterpretation of clauses. This will increase contract readability which will ultimately reduce any possible misinterpretation by SME contractors. The low responses were a limitation, however, the explanatory nature of the study supports the validity of the initial findings. Further study based on a national basis, is recommended.

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Barriers and Adoption Strategies for Modular Construction in South Africa

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Abstract

Modular construction, a modern, contemporary approach to construction, involves crafting modules in a controlled factory setting and assembling them on-site. Modular construction signifies a departure from conventional construction methods, highlighting a vital evolution necessary for modernising the South African construction industry. While recognised as a viable construction method, its full potential remains untapped in developing nations like South Africa despite its benefits, such as accelerated construction time, eco-friendliness, and reduced waste. This paper primarily aims to investigate the limiting factors hindering the adoption of modular construction, explore strategies to improve the adoption of modular construction and attempt to identify key role players in the adoption process of modular construction in South Africa. The study employed a mixed-method approach, utilising a close-ended questionnaire distributed via Google Forms to 100 construction professionals in South Africa and conducting 10 semi-structured interviews via Microsoft Teams. The data was analysed using the statistical analysis tools in Microsoft Excel. The study identified key barriers to modular construction in South Africa: lack of awareness, fear of job losses, logistical constraints, negative perceptions, and insufficient financial backing. Strategies for adoption improvement involve public awareness campaigns, specific regulations, government incentives, and training programs. The study further concluded that construction firms and construction professionals play a pivotal role in adopting and implementing modular construction. Further research is needed to explore the complex dynamics surrounding the perceived fear of job losses and its impact on adopting modular construction in South Africa. Practical implications include addressing job loss concerns through public awareness as the most effective strategy based on the research data, tailored regulations, and proactive industry involvement. This paper aims to give stakeholders insight to foster collaboration among industry players, researchers, and policymakers, advancing South Africa's construction industry.

Keywords: Modular Construction, Off-site Construction, Modern Methods of Construction, Prefabrication.

Introduction

While modular construction has been heralded as a potential solution to housing deficits and construction inefficiencies in developed countries, its adoption in developing economies like South Africa faces significant barriers. The construction method offers a myriad of economic and environmental benefits for a more sustainable construction industry, ideal for the rapid growth required for a developing country like South Africa. Modular construction is a widely known method of construction that can alternatively be referred to as off-site construction, where modules of a building are manufactured in different building materials such as wood or steel (National Institute of Building Sciences, 2016). In most cases modular construction involves constructing modules that are fitted with the electrical, plumbing, and mechanical work, this work is done off-site at a factory (Pan, Gibb & Dainty, 2007) with controlled conditions to ensure high-quality work (Godbole, Lam, Mafas, Fernando, Gad & Hashemi, 2018). The use of this method of construction has been increasing over the years mainly because of its benefits compared to traditional construction methods, these benefits include reduced costs, faster construction time and improved quality (Lawson, Ogden & Goodier, 2014: 7-8). Bello, Khan, Idris & Awwal (2023) added that other major drivers include, waste reduction, safety performance, productivity performance and standardisation.

Throughout the years the use of modular and modern methods of construction has increased globally (Rahman, 2014:69), especially in developed countries such as Japan and Sweden (Manley & Widen, 2019). These two countries are leaders in modular buildings, the reason behind this high percentage is that each country had to adopt an alternative way to construct to meet the housing demand (Manley & Widen, 2019). Conversely, the adoption of modular construction remains notably low in developing countries, particularly across the African continent (Mostafa, Dumrak, Chileshe & Zuo, 2014; Aigbavboa, Aghimien & Ntso, 2018; Bello, Khan, Idris & Awwal, 2023). Notably, South Africa reflects a modest adoption rate, with approximately 3-4% of its commercial buildings employing modular construction methods (Dupwa, 2017). Despite the evident success and prevalence in developed nations, the uptake of modular construction in developing countries, including those in Africa, is yet to experience a substantial surge.

In view of the above, this paper set out to answer the following research questions: Firstly, what are the limiting factors hindering the adoption of modular construction in South Africa? Secondly, how can the adoption of modular construction in South Africa be improved? Third and lastly, who are the role players in adopting and implementing modular construction in South Africa?

Understanding the challenges and barriers to adopting modular construction helps in pin-pointing specific obstacles faced by the construction industry. This knowledge allows stakeholders to systematically address these barriers and limitations, paving the way for a smoother adoption process. The modular construction industry has the potential to revolutionise the traditional construction industry by offering efficiency, speed, and sustainability. Identifying limiting factors allows for strategic interventions that can spur industry growth, creating new opportunities for businesses and professionals. Identifying limitations fosters collaboration among industry players, researchers, and policymakers.

In conclusion, examining the factors that limit the use or adoption of modular construction in South Africa is pivotal for unlocking the full potential of this innovative construction method. It enables stakeholders to develop targeted strategies, foster collaboration, and create an environment conducive to the widespread adoption of modular construction, ultimately contributing to the advancement of the construction industry in South Africa.

Literature Review

Adoption barriers

As posited by Ali, Kineber, Elyamany, Ibrahim and Daoud (2023:3347), the introduction of modular construction has proven disruptive for the construction industries in developing countries, necessitating substantial deviations from traditional construction practices. Similarly, Bello et al. (2023) contend that developing nations, face formidable challenges in adopting modular construction despite its myriad advantages. Despite the potential benefits, the assimilation and execution of modular construction encounter hindrances and constraints. South Africa is no exception and despite the myriads of advantages inherent to modular construction, obstacles and constraints hinder the assimilation and execution of modular construction.

According to Lim, Ling, Tan, Chong, & Thurairajah, (2022), modular construction are mostly used and widely adopted in developed countries such as Sweden, the US and Japan to address issues that the construction industry faces related to cost, quality duration and safety. In contrast, the adoption of modular constructions in developing countries is relatively still low because this is due to the limitations that prohibit the adoption of modular constructions and the lack of enablers that would accelerate its adoption (Aigbavboa, Aghimien, & Ntso, 2018). In South Africa, the use of modular construction is limited with only 3-4% of commercial buildings being constructed using this method. Developed countries such as Sweden, the US and Japan all had enablers that accelerated the adoption of modular for example, Sweden's construction industry was faced with weather issues that resulted in a decrease in construction projects (Bertram, et al., 2019).

A review of existing literature on the limitations in the use of modular construction revealed a dearth of literature in a South African context. However, in the international discourse on modular construction limitations, a consistent thread emerges as scholars and practitioners delve into the intricacies of this construction approach. Common themes emerging from the literature on the use of modular

construction globally revealed mainly cost considerations, skills and labour challenges, regulatory and policy constraints, technical and design challenges, and perception issues among others.

In a research endeavor conducted by Rahman (2014:74), a survey presented twenty-nine (29) factors, out of which twenty-six (26) were recognised as significant impediments. Notably, the most noteworthy barriers identified included inflexibility in design change, higher initial costs, and the potential for an elevated overall expenditure. The respondents for this study were drawn from both the United Kingdom and China, and it is essential to highlight that the survey results from these two countries exhibited disparities, showcasing distinct priorities and perspectives.

In a more recent investigation undertaken by Wuni & Shen (2020), a comprehensive international review of existing studies unveiled a staggering 120 identified barriers hindering the adoption of modular construction. This extensive study scrutinised results from 15 countries spanning Asia, Africa, North America, Europe, and Australia. The researchers argued that these 120 constraints could be categorised into knowledge, attitudinal, industry, financial, aesthetic, technical, process, and policy-related barriers.

Agapiou (2022:283) referenced twenty-four (24) themes considered as barriers to modular construction in the United Kingdom. However, evidence derived from his research suggests that barriers related to costs were perceived as the most significant, followed by supplier capacity and end-user preferences for traditional construction.

In a study conducted by Ali et al. (2023:3360) within an Egyptian context, primary barriers were identified and ranked in descending order as technical, knowledge, attitudinal, process, and financial hurdles. Additionally, Bello et al. (2023) identified, and analysed nine (9) significant hurdles, encompassing financial, operational, governmental, knowledge-related, technical, logistical, industry-specific, attitudinal, and aesthetic barriers. All nine hurdles were statistically deemed significant, shedding light on their considerable impact within the context of modular construction.

Based on the existing literature, the majority of authors have pinpointed analogous constraints hindering the adoption of modular construction. These diverse authors align with prior research findings regarding the factors recognised as impediments to the widespread acceptance of modular construction. It is noteworthy that while comparable limitations were acknowledged, their priority or significance exhibited variation across different countries. Consequently, the synthesis of literature leads to the conclusion that future research endeavors should concentrate on scrutinising the following identified limitations or barriers: financial, knowledge-related, technical, attitudinal, and policy constraints. This nuanced understanding aims to guide targeted investigations, facilitating a more nuanced comprehension of the distinctive challenges posed by modular construction in diverse geographical contexts.

Role players contributing to the adoption of modular construction

Clients

Clients play a significant role in promoting innovations including modular construction (Ribeiro, Arantes, & Cruz, 2022). For modular construction to be used for a specific project, the client needs to agree to its use and when delivered successfully this can then help remove the poor perception of modular construction in a community and create awareness of the construction method (Schmidt, 2020).

Government

According to Bello et al., (2023:111) the government played an important role in countries such as Sweden and the US that resulted in a positive implementation of modular construction. The government's role in implementing modular construction includes developing building regulations and codes that specifically cater for modular construction, this will make compliance approvals and design development simpler (Schmidt, 2020).

Construction professionals/construction industry

The construction industry plays a crucial role in the implementation of modular construction (Schmidt, 2020). Construction professionals possess extensive knowledge and expertise in the construction field and therefore, can work together with the government to create building regulations and codes that are

specifically for modular construction and work together with educational institutions to provide training and educational knowledge to construction students (Bello et al., 2023).

Educational institutions

To accelerate the implementation of modular construction educational institutions can provide research and information on the topic of modular construction. Educational institutions can also develop their construction courses around modular construction designs, materials and construction methods (Bello et al., 2023).

In conclusion, modular construction in South Africa is reliant on the proactive involvement of multiple role players to ensure successful adoption and implementation. Government plays a significant role by ensuring a environment conducive for the growth of the construction method and by development of a regulatory framework for the construction method. Higher educational institutions and academia is vital role players providing training, education and generating research opportunities on modular construction. Collaboration between all key stakeholders can increase the adoption of modular construction, creating opportunities for transformation of the construction industry to more efficient, sustainable and innovative solutions.

Research Methodology and Method

This study adopted a mixed method approach, incorporating both qualitative and quantitative research methods to investigate the factors that limited the widespread adoption of modular construction in South Africa and to explore strategies for mitigating these limitations. Qualitative data were collected from construction professionals in South Africa using a semi-structured interview data collection tool. The interview requests were intentionally disseminated via email. Interview and survey questionnaires focussed on existing barriers to modular construction outlined in the literature review. In addition to the existing barriers identified by the literature review, the author added factors believed to be barriers in a South African context.

A semi-structured interview proved effective for gathering qualitative data as it allowed participants to articulate their views and discuss potential measures to enhance the utilisation of modular construction, as well as identify factors constraining its use in South Africa. The semi-structured interviews were conducted online via Microsoft Teams. To collect quantitative data, a close-ended survey questionnaire was employed. This questionnaire was distributed randomly via email to South African construction professionals. This survey format was selected because it facilitates the collection of closed-ended responses that can be statistically analysed to identify factors hindering the widespread adoption of modular construction in South Africa. The survey questions were distributed via email as an online link to Google Forms. In this study, a sample size of 100 participants was chosen by random probability sampling method for the quantitative survey approach and 10 participants was chosen by purposive sampling for the qualitative interview approach. Purposive sampling was used in this study to identify participants based on expert knowledge and experience in the concepts articulated in this research. The qualitative data from the interviews in the study was analysed through thematic analysis. After conducting semi-structured interviews, the data was analysed by identifying patterns or themes that emerged in the responses. Specifically, repeated phrases or concepts were noted and grouped according to the interview questions. This thematic grouping enabled the researcher to categorise and discuss the insights provided by the respondents in a descriptive format. The common themes identified were then discussed in relation to the research objectives, offering deeper insights into the barriers and strategies for adopting modular construction in South Africa.

Research Results

This research aimed to investigate the factors contributing to the South African construction sector's reluctance to embrace modular construction. A response rate of 40% for the quantitative study (online survey) was achieved, while 50% of the respondents were available to be interviewed. The survey questionnaire was organised into four distinct sections, aligning with the study's objectives to capture relevant data patterns systematically. Descriptive statistical analysis was employed to analyse the raw data, facilitating the exploration of findings pertinent to each objective. Subsequently, the insights gleaned from the study were utilised to refine the research question and address the overarching aim

of unravelling the reasons behind the construction industry's hesitancy in adopting modular construction practices in South Africa.

Demographic analysis

This portion of the quantitative research questionnaire comprised inquiries concerning the participants' professional background, experience, gender, and geographical location. Its objective was to discern the diversity within the demographic composition of the respondents. 48% of the respondents hailed from the Free State, with 33% from Gauteng, 8% from Limpopo, 5% from the Eastern Cape, 5% from KwaZulu-Natal, and 3% from North-West Province. In terms of gender distribution, 63% were male and 38% were female. Regarding professional roles, 35% were Construction Managers, 33% were Quantity Surveyors, 15% were in other construction-related professions, 10% were Project Managers, 5% were Architects, and 3% were Health and Safety officers or managers. Experience-wise, 67% had 0-5 years, 13% had 6-10 years, 10% had 11-16 years, 8% had 17-20 years, and 3% had over 20 years of experience. Additionally, 66.7% worked in private organisations, while 33% were employed in public entities. A high percentage of unexperienced respondents is not uncommon and illustrate the possibility of more experienced professionals not utilising electronic surveys or their unavailability due to time restraints. Conversely, younger professionals often demonstrate greater innovation and adaptability to alternative methods of construction compared to their more seasoned counterparts.

However, the results from the qualitative study (semi-structured interviews) revealed that all respondents had more than 5 years of experience, while all respondents indicated a high degree of knowledge of the use of modular construction. The findings revealed a diverse spectrum of respondents concerning their professional registration status, geographical location, gender, and experience, which indicated a good representation of the wider population and should provide credible data for the survey.

Barriers that limit the use of modular construction in South Africa

To evaluate the impediments hindering the adoption of modular construction in South Africa, some barriers outlined in the literature review were presented to the participants. They were then prompted to identify which barriers they perceived as limiting the utilisation of modular construction in the country.

The findings were visualised in a bar graph, depicted in Figure 1.

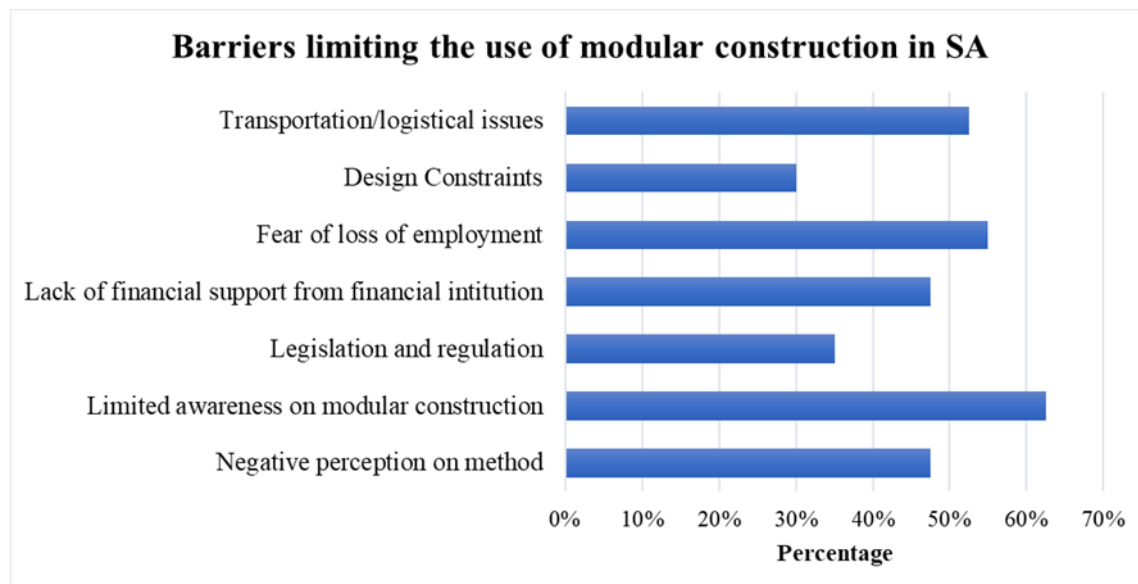


Figure 1: Barriers limiting the use of modular construction in South Africa

The results indicated that the most significant barriers were identified as the lack of awareness on modular construction (selected by 63% of participants), followed by concerns regarding potential job losses (selected by 55% of participants), logistical constraints (selected by 53% of participants), negative perceptions (selected by 48% of participants), and insufficient financial backing from lending

institutions (selected by 48% of participants). The identification of the potential for loss of employment is a significant barrier and has not yet been identified by other studies as a significant barrier. Furthermore, the respondents were asked to indicate other barriers that they believed contribute to the limited use of modular construction in South Africa and their responses mainly identified lack of knowledge, availability of skilled labour and fear of change.

The results of the semi structured interviews confirmed indication from the survey that a general perception of fear for job losses is a significant barrier to the use of modular construction in South Africa. When interviewees were tasked to rate the impact of modular construction on the employment rate in South Africa, on a scale of 1 to 5, with 1 being no negative impact and 5 being high impact, 80% of respondents indicated a 4 & 5. This confirms previous indications that the fear of jobs losses or the potential for increased unemployment is a significant limiting factor identified by the study.

Ways to increase the adoption and implementation rate of modular construction in South Africa

To propose the ways in which the adoption and implementation rate of modular construction in South Africa could be increased, the author opted to propose some strategies identified by available literature, that is believed to potentially increase the adoption rate of modular construction. The results indicated that public awareness campaigns and regulations and building codes specific for modular construction and government incentives to construction companies that use modular construction were perceived by study participants to be the most effective strategies to increase the adoption and implementation of modular construction in South Africa. The highest ranking (most effective) strategy to increase adoption of modular construction based on the research data were identified as public awareness campaigns. This strategy further also addresses the main barrier identified by the research data, being the limited awareness of modular construction. The lowest-ranked strategies were identified by respondents as having support from financial institutions, which possibly indicates a low influence from financial institutions.

Respondents were also tasked with proposing other possible strategies to improve the adoption and implementation of modular construction. Training, research and education were suggested by 59% of respondents while 18% suggested collaboration between public and private sectors, which could suggest higher educational institutions to possibly have a role in the adoption and implementation of the construction method.

Role players that contribute to the adoption and implementation of modular construction in South Africa

Five role players were identified from the literature review and presented to the respondents to assess the role players that contribute to the adoption and implementation of modular construction. The respondents were asked to indicate one role player they believed to play a role in adopting and implementing modular construction. The findings were visualised in a pie graph, depicted in Figure 2.

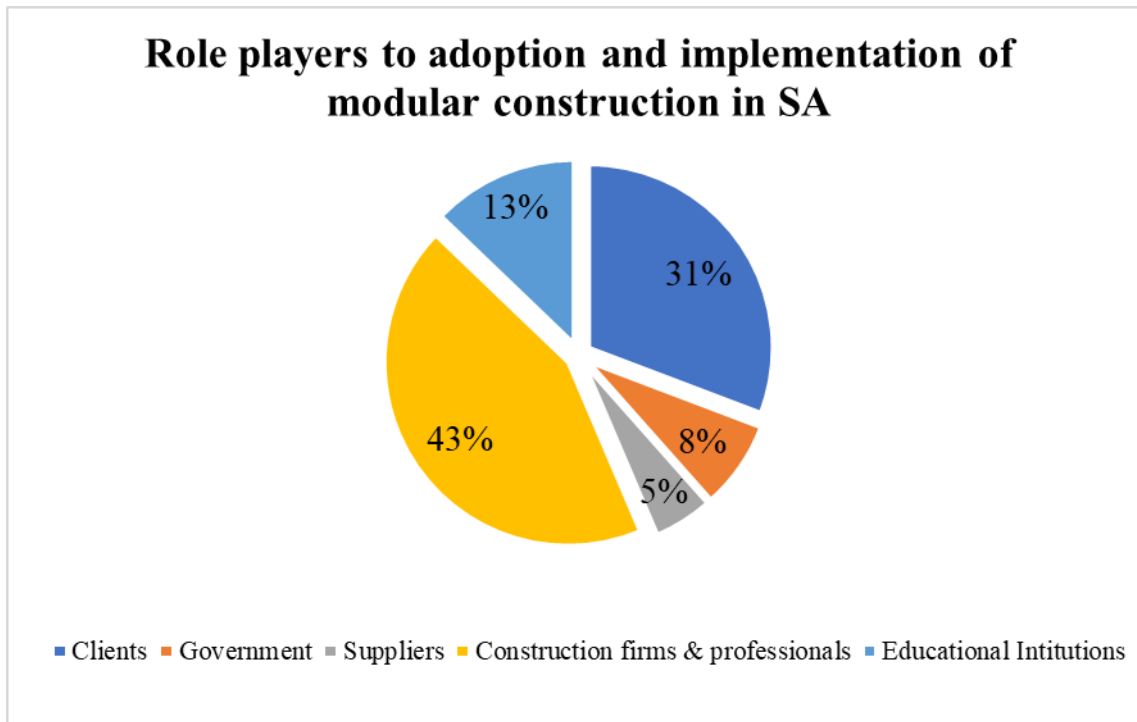


Figure 2: Role players to the adoption and implementation of modular construction in SA

The data collected from the survey had demonstrated a general perception that construction firms and professionals have the most important role to play in the adoption and implementation of modular construction in South Africa. Clients, followed by educational institutions, was deemed the second and third most important role player in the adoption and implementation of modular construction. The results from the semi-structured interviews also indicated that 60% of respondents felt that construction firms and professionals were the most important role player and equally second with 20% respectively clients and government. From the results, it can be concluded that construction firms and construction professionals play a major role in adopting and implementing modular construction in South Africa.

Discussions

The study mainly explored the factors contributing to the South African construction sector's reluctance to embrace modular construction. The main question that needed to be addressed was which barriers hinders the adoption and implementation of modular construction in South Africa. In addressing this question, the limitations that affect the adoption and implementation were evaluated and some indications from previous studies by Aigbavboa, Aghimien & Ntso (2018:1251) were confirmed. However, this study uncovered another significant factor that respondents perceived to limit the adoption and implementation of modular construction, the potential for increased unemployment. The study by Aigbavboa, Aghimien & Ntso (2018) found that South African prefer the use of traditional construction methods, however, it failed to identify the potential for increased unemployment or the fear of jobs losses as the main contributing factor for this preference. The perceived fear of job losses among construction workers due to the adoption of modular construction in South Africa is a significant concern that arises from the potential shift in construction practices. Modular construction, with its off-site manufacturing processes and assembly line production of building components, has the potential to streamline construction projects, reduce labour requirements, and increase efficiency. While these benefits are advantageous for project timelines and costs, they also raise apprehensions among construction workers regarding the future of their employment.

One of the primary reasons for the fear of job losses is the perception that modular construction could automate or replace traditional on-site construction tasks, leading to a reduced demand for manual labour. Workers may feel that their skills and expertise in traditional construction methods could become obsolete, making them vulnerable to unemployment. Additionally, the transition to modular construction

may require workers to adapt to new technologies, techniques, and job roles, which can further contribute to uncertainty and resistance.

Further, the study set out to determine ways to improve the adoption of modular construction in South Africa. The study found that public awareness campaigns, regulations and building codes specific for modular construction, government incentives to construction companies that use modular construction and training, research and education could offer viable strategies to improve the adoption and implementation of modular construction in South Africa. The last research question to be satisfied was identifying the role players contributing to adopting and implementing modular construction in South Africa. The study concluded that construction firms and construction professionals have the most important role in adopting and implementing modular construction in South Africa. Construction firms and professionals play a pivotal role in adopting and implementing modular construction in South Africa. They are at the forefront of driving innovation and technological advancement in the industry. Their investment in research, development, and implementation of modular construction techniques is essential for demonstrating this approach's feasibility, efficiency, and effectiveness.

Construction professionals, including architects, engineers, project managers, and skilled laborers, are instrumental in the design, planning, coordination, and execution of modular construction projects. Additionally, firms and professionals advocate for the benefits of modular construction, educate stakeholders, and address any concerns or challenges that arise during the adoption process. Their expertise, collaboration, and proactive involvement are essential for successfully integrating modular construction into South Africa's built environment, offering benefits such as efficiency, cost-effectiveness, and sustainability. Their advocacy, knowledge-sharing, and expertise contribute to broader acceptance and integration of modular methods. Ultimately, their proactive involvement is crucial for realising the efficiency, cost-effectiveness, and sustainability benefits of modular construction in South Africa's built environment.

Conclusion

In conclusion, the study primarily delved into the factors hindering the South African construction sector's adoption of modular construction, pinpointing job loss concerns as a significant adoption barrier. While prior research identified preferences for traditional methods, our study illuminated the fear of unemployment stemming from modular construction's potential to automate tasks. In a country where construction projects are critical for employment, the threat posed by a reduced labor force and job security proves to be a massive barrier to modular construction. The challenges faced by the modular construction is further exacerbated by the construction methods' need for high initial capital and the lack of specialised suppliers.

Addressing these barriers requires a holistic approach in South Africa. Highlighting the benefits of modular construction, like reduced construction time, sustainability and reduced construction waste should be at the forefront of public awareness campaigns. The research underscores the importance of public awareness campaigns, tailored building codes and regulations, government support incentives to construction companies, and education as proposed strategies to address these challenges.

Construction firms and professionals play a pivotal role in driving innovation, advocating for change, and ensuring successful integration. By taking a leading role, they can significantly contribute to reshaping public perceptions, influencing policy development, and ensuring that modular construction's sustainability and efficiency benefits are realised in South Africa's built environment. Their proactive involvement is vital for realising the efficiency and sustainability benefits of modular construction in South Africa's built environment.

The successful integration of modular construction into the South African construction sector will require a collective effort across government, private sector, and educational institutions to overcome the barriers and harness the numerous economic and environmental advantages it offers.

Recommendations

The practical implications of the study underscore the need to address job loss concerns in South Africa's adoption of modular construction. Public awareness campaigns, tailored regulations, and proactive involvement of construction firms and professionals can achieve this.

Based on the widespread fear of job losses identified by 55% of respondents, it is recommended that public awareness campaigns focussing on new jobs opportunities presented by modular construction, should be rolled out to the wider public in South Africa. The awareness campaigns should focus to create partnerships with media, professionals in the construction industry and higher educational institutes. Government should furthermore establish a modular construction task team comprising industry professionals, regulatory bodies and academia, to address certification for workers transitioning from conventional construction to modular construction and to develop modular construction industry specific regulations and building codes. Government and private firms should collaborate to implement subsidised modular technique training programs to construction workers at risk of displacement. These practical recommendations provides a framework for overcoming the barriers identified by the study, thereby ensuring a actionable path towards implementation.

While the study offers valuable insights, caution is warranted in extrapolating its findings due to its small sample size. Additional research is advised to validate and expand upon these results with a larger and more diverse sample. Specifically, further investigation is needed to explore the complex dynamics surrounding the perceived fear of job losses and its impact on adopting modular construction in South Africa.

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Building Maintenance Technologies and Barriers to Adoption Among South African Construction Professionals

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Abstract

The effective maintenance of buildings is crucial for extending their lifespan and optimising performance. With the increasing complexity of building systems and the potential benefits of technology, this study's objectives are to identify the types of building maintenance technologies employed in South Africa and the primary barriers hindering their widespread adoption. A quantitative research approach was adopted, utilising an online questionnaire survey. Participants included construction professionals registered with SACPCMP. A convenient sampling method was employed. Of the 213 distributed questionnaires, 110 were returned, yielding a 52.1% response rate. Data analysis was conducted using Stata version 17. The findings revealed that cybersecurity concerns, legal issues, and a lack of training are the primary barriers to adopting building maintenance technologies in South Africa. The study also noted that the overall uptake of these technologies remains slow despite their potential benefits. The study is limited by its reliance on self-reported data and the cross-sectional research design. Future research could explore causal relationships between barriers and technology adoption. The findings underscore the need for targeted interventions to address cybersecurity concerns, clarify legal frameworks, and invest in training programs to accelerate technology adoption. This research provides valuable insights for industry stakeholders, including building owners, maintenance managers, and technology providers. Organisations can develop targeted strategies to overcome these challenges and enhance maintenance practices by understanding the barriers to technology adoption. This research contributes to the body of knowledge on building maintenance technology adoption in South Africa. It informs industry stakeholders about key barriers and supports the transition towards more efficient and effective building maintenance practices, potentially leading to improved sustainability and performance.

Keywords: Adoption, Barriers, Building Maintenance, South African Organisations, Technologies.

Introduction

When a building is completed, it is assigned a specific function and an estimated life cycle (Yasin et al., 2019; Sampaio, 2016). While the idea of a maintenance-free building remains elusive, maintenance begins immediately upon construction (Yasin et al., 2019). Proper maintenance can control and slow the deterioration process, thereby extending the building's lifespan (Sampaio, 2016). Effective maintenance not only ensures the building functions optimally but also enhances the health, safety, and well-being of occupants and the surrounding community (Eze, Obaje and Zubairu, 2018). As technology continues to evolve, its role in improving building maintenance becomes increasingly significant. Chen and Tang (2019) highlight that inefficient maintenance planning often stems from inadequate methods and techniques for predicting uncertainties and estimating costs. The integration of advanced technologies in building maintenance has been progressively acknowledged, with significant recognition in countries like the United Kingdom for technologies such as Building Information Modeling (BIM) (Love et al., 2015). These advancements are critical in addressing productivity challenges within the construction industry.

Despite the potential benefits of technologies like BIM, the adoption has been slow, exacerbated by barriers such as stakeholder resistance, limited facilities management knowledge, inadequate communication between designers and facility managers, cybersecurity issues, and legal concerns (Ahmed, 2018; Eadie, Rocks and Stoyanov, 2017; Jain et al., 2020; Wong et al., 2014). Understanding these barriers is crucial for developing strategies that can overcome them, thereby enhancing the adoption of technologies in building maintenance.

The research aims to provide insights into how digital technologies can be effectively adopted and integrated into maintenance practices to address industry challenges. Two objectives are designed to achieve this aim, including to identify the types of building maintenance technologies employed in South Africa and the barriers hindering the widespread adoption of the technologies. The study contributes to the ongoing digitalisation in maintenance, emphasising the need for adaptation to technological advancements and improved efficiency, which will enhance the tasks of quantity surveyors when required to quantify tasks of maintaining buildings. The research supports the transition towards more efficient and effective building maintenance practices to adapt to changes in technology, sustainability, and industry dynamics.

Literature Review

BIM potential and implementation challenges in building maintenance

The potential and barriers associated with the implementation of BIM in Facilities Management is evident in the literature. On the potential side, BIM offers comprehensive access to project information throughout a building's lifecycle, improving aspects such as commissioning, quality control, energy management, maintenance, repair, and space management (Becerik-Gerber et al., 2012; Naghshbandi, 2017). It ensures stakeholders have accurate and updated data, allowing virtual visualisation of the project pre-construction to identify potential risks (Ahmed, 2018). Despite these benefits, BIM faces significant barriers, including resistance to change, limited FM knowledge, high costs, and lack of awareness (Ahmed, 2018; Love et al., 2015). There are also issues with insurer hesitance, poor communication between designers and facility managers, challenges in data management, and legal uncertainties (Eadie, Rocks and Stoyanov, 2017; Naghshbandi, 2017; Love et al., 2015). Without a concerted effort to address these barriers, the full potential of BIM in Facilities Management may remain unrealised.

Internet of Things potential and implementation challenges in building maintenance

The Internet of Things (IoT) improves building maintenance by enabling seamless device connections (Jain et al. 2020; Vashi et al. 2017), reducing human intervention (Vashi et al. 2017), and ensuring all stakeholders have access to shared information. RFID systems enhance object identification and provide extensive data storage (Flanagan et al. 2014), while IoT can transform buildings into smart environments, by optimising performance and comfort it is fraught with challenges. These barriers include security risks such as hacking and tampering, information overload from RFID tags, and the complexity of system deployment and interoperability issues.

Geographical Information System potential and implementation challenges in building maintenance

The potential of the Geographical Information System (GIS) in building maintenance includes improved accuracy in locating and managing components, cost reduction, and the ability to work with other technologies (Rich and Davis, 2010; Wong, Ge, and He, 2018). Barriers involve high costs of integration and the need for further development, particularly for interior FM applications (Rich and Davis, 2010; Wong, Ge, and He, 2018). These insights highlight GIS's role in enhancing FM while also noting the challenges that must be addressed for its more effective use.

Virtual Reality potential and implementation challenges in building maintenance

Virtual Reality (VR), which originated in the 1980s, provides immersive digital experiences without physical construction (Slater and Sanchez-Vives, 2016). In Facilities Management (FM), VR enhances communication among construction teams by creating a 3D virtual environment, which aids in

maintenance by offering detailed views of building components and addressing issues with 2D drawings and as-built information (Akanmu, Olayiwola and Olatunji, 2020). VR facilitates accurate inspections, reduces costs, and improves productivity by allowing maintenance specialists to access previous inspection records and integrate with FM software (Carreira et al., 2018; Sampaio, 2016). Despite these benefits, challenges include user unfamiliarity with VR environments and difficulties in linking model information (Sampaio, 2016), which need to be addressed to fully leverage VR's potential in building maintenance.

Cloud Computing potential and implementation challenges in building maintenance

Cloud computing provides on-demand network access to shared computing resources, including storage and processing capabilities, through mobile phones and personal computers at minimal cost (Botta et al., 2015; Wong et al., 2014). In building maintenance, cloud computing, when integrated with BIM, forms Cloud-BIM, which enhances real-time communication, data storage, and access, benefiting stakeholders, especially those joining later in the project (Akanmu, Olayiwola and Olatunji, 2020; Carreira et al., 2018; Wong et al., 2014). Cloud-BIM helps identify maintenance needs, access records, and monitor progress, though its use is more common in early stages rather than during later maintenance phases (Wong et al., 2014). Cloud computing also supports predictive maintenance in manufacturing, suggesting potential benefits for building maintenance (Wang et al., 2017). However, challenges include legal, security, and privacy issues, as well as the need for proper training and management (Wong et al., 2014; Redmond et al., 2012). Cloud computing enables efficient information sharing and updates, though it may affect work visibility and stakeholder preferences (Redmond et al., 2012).

Research Methodology and Method

The research adopts a positivist epistemology, aimed at testing a known theory to answer the research question. It uses a deductive approach, justified using a questionnaire survey to collect data for evaluating existing literature (Saunders et al., 2016). The study's target population consisted of 476 professionally registered individuals from the South African Council for the Project and Construction Management Professions (SACPCMP) and the South African Facilities Management Association (SAFMA). Although both SACPCMP and SAFMA were initially targeted, only professionals registered with SACPCMP participated in the study. Raosoft software calculated that, with a 95% confidence level and a 5% margin of error, a sample size of 213 was appropriate. Convenient sampling was employed, with SACPCMP aiding in data collection through their professional list. Participants were selected via organisational contacts and social media (Saunders et al., 2016). Out of the 213 sampled, 110 completed the questionnaire, yielding a 52.1% response rate, deemed sufficient as a response rate above 33% is generally acceptable (Lindemann, 2019). Primary data was collected through a questionnaire focused on demographic variables and critical success factors. The electronic questionnaire, created with Google Forms, was distributed via LinkedIn and the Council for the Built Environment (CBE), with SACPCMP being the primary assisting council. Electronic surveys were chosen for their broad reach (Nayak and Narayan, 2019).

Data analysis was performed using Stata version 17. Mean values, frequencies, and standard deviations were used for data interpretation. Descriptive findings were analysed using a scale where 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly agree, with variables ranked by mean values and standard deviations. To allow interpretation of mean scores for building maintenance technologies employed in South Africa, the following classifications were considered: strongly disagree (≥ 1.00 and ≤ 1.80), disagree (≥ 1.81 and ≤ 2.60), neutral (≥ 2.61 and ≤ 3.40), agree (≥ 3.41 and ≤ 4.20), and strongly agree (≥ 4.21 and ≤ 5.00) (Renault, Agumba, and Ansary (2018). The data for the second research objective, which involves barriers hindering the widespread adoption of building maintenance technologies was interpreted by categorising responses into Yes (Strongly Agree), No (Strongly disagree and Disagree), and Neutral. Reliability analysis was conducted to ensure the internal consistency of the survey instrument. A Cronbach's alpha of 0.80 or above demonstrates excellent reliability (Ursachi, Horodnic, and Zait, 2015: 681). The overall Cronbach's alpha was 0.9235, indicating high reliability.

Research Results

Building maintenance technology in use

Table 1 shows the adoption of building maintenance technologies. Responses regarding the application of technology were rated using the agreement scale. Considering the mean score range used for result interpretation: strongly disagree (≥ 1.00 and ≤ 1.80), disagree (≥ 1.81 and ≤ 2.60), neutral (≥ 2.61 and ≤ 3.40), agree (≥ 3.41 and ≤ 4.20), and strongly agree (≥ 4.21 and ≤ 5.00), the overall average mean score for the application of technology is 2.54, with a standard deviation of 1.15. The mean score of 2.54 falls within the scale range of Disagree (≥ 1.81 and ≤ 2.60), indicating that respondents generally disagree that there is an existing use of technologies for maintaining buildings in South Africa.

Table 1: The application of technology for building maintenance

Code	Observation	Response (%)					Mean	Std. dev.	Minimum	Maximum	Ranking
		No		N	Yes						
		SD	D		A	SA					
AoT-4	88	12.50	25.00	35.23	20.45	6.82	2.84	1.10	1	5	1
AoT-6	88	15.91	34.09	23.86	15.91	10.23	2.71	1.22	1	5	2
AoT-3	88	21.59	29.55	23.86	19.32	5.68	2.58	1.19	1	5	3
AoT-1	88	26.14	23.86	31.82	13.64	4.55	2.47	1.15	1	5	4
AoT-2	88	27.27	31.82	25.00	12.50	3.41	2.33	1.11	1	5	5
AoT-5	88	30.68	27.27	26.14	12.50	3.41	2.31	1.14	1	5	6
Overall							2.54	1.15			

Barriers to technology adoption

The analysis of questionnaire data regarding barriers to technology adoption is represented in Table 2. Descriptive statistics, including mean scores, standard deviations (Std. dev.), and percentages were used. The scale ranges used for building maintenance technology in use: strongly disagree (≥ 1.00 and ≤ 1.80), disagree (≥ 1.81 and ≤ 2.60), neutral (≥ 2.61 and ≤ 3.40), agree (≥ 3.41 and ≤ 4.20), and strongly agree (≥ 4.21 and ≤ 5.00) was also applied to barriers to technology adoption. As shown in Table 2, the participants' responses regarding the barriers to technology adoption indicate agreement and strong agreement that these barriers hinder the adoption of technology for building maintenance in South Africa. The mean scores fall within the scale ranges of agree = 4 (≥ 3.41 and ≤ 4.20) and strongly agree = 5 (≥ 4.21 and ≤ 5.00), while the overall mean score of 3.89 falls within the ranges of agree.

Table 2: The analysis of the barriers to technology adoption

Code	Observation	Response (%)					Mean	Std. Dev.	Minimum	Maximum	Ranking
		SD	D	N	A	SA					
B-9	88	4.55	4.55	11.36	21.59	57.95	4.24	1.11	1	5	1
B-5	88	5.68	5.68	12.50	19.32	56.82	4.16	1.19	1	5	2
B-8	88	5.68	4.55	13.64	25.00	51.14	4.11	1.16	1	5	3
B-6	88	3.41	3.41	22.73	20.45	50.00	4.10	1.08	1	5	4
B-14	88	5.68	7.95	15.91	25.00	45.45	3.97	1.21	1	5	5
B-10	88	2.27	12.50	18.18	23.86	43.18	3.93	1.15	1	5	6
B-1	88	3.41	10.23	26.14	15.91	44.32	3.88	1.19	1	5	7
B-7	88	6.82	5.68	23.86	20.45	43.18	3.88	1.23	1	5	8
B-2	88	1.14	10.23	26.14	26.14	36.36	3.86	1.06	1	5	9
B-3	88	4.55	6.82	23.86	31.82	32.95	3.82	1.11	1	5	10

B-11	88	4.55	10.23	27.27	17.05	40.91	3.80	1.21	1	5	11
B-13	88	9.09	4.55	31.82	21.59	32.95	3.65	1.24	1	5	12
B-12	88	10.23	9.09	26.14	25.00	29.55	3.55	1.29	1	5	13
B-4	88	5.68	14.77	27.27	25.00	27.27	3.53	1.20	1	5	14
Overall	88						3.89	1.18			

Discussion

Building maintenance technology in use

Existing use of Cloud Computing (AoT-4)

Table 1 presents the use of Cloud Computing to aid building maintenance AoT-4 (Existing Use of Cloud Computing) holds the highest ranking, i.e., 1st, and was rated as neutral with a mean score of 2.84 and a standard deviation of 1.10. This suggests the respondents were undecided of its use. Additionally, 35.23% of respondents indicated neutrality. When responses are grouped into three categories—Yes (Strongly Agree and Agree), No (Strongly Disagree and Disagree), and Neutral—the percentage of respondents who disagree with the existence of Cloud Computing use is higher, at 37.50%. The percentage of respondents who agree that Cloud Computing is used is 27.27%. This suggests a slow adoption of Cloud Computing for building maintenance in South Africa. Although Cloud Computing is used for maintenance in the manufacturing industry (Wang et al., 2017), its adoption for building maintenance in South Africa remains slow.

Existing use of GIS (AoT-6)

Table 1 indicates the use of GIS to aid building maintenance. The existing use of Cloud Computing is followed by AoT-6 (Existing Use of GIS), which is ranked 2nd and rated neutral with a mean score of 2.71 and a standard deviation of 1.22. This indicates that respondents are not convinced whether GIS is used or not used. As shown in Table 1, exactly half of the respondents, or 50%, strongly disagree and disagree that there is an existing use of GIS for building maintenance. This suggests a slow adoption of GIS for building maintenance. Although Rich and Davis (2010) indicate that GIS has been used in facilities management for years, the results still reflect a slow pace in adopting GIS for building maintenance.

Existing use of IoT (AoT-3)

The existing use of IoT received a mean score of 2.58 with a standard deviation of 1.19, ranking 3rd and rated as “disagree.” This indicates that respondents do not believe there is an existing use of IoT to aid building maintenance in South Africa. As shown in Table 1, the result shows that over half (51.14%) of the respondents strongly disagree and disagree with the notion that IoT is used to assist in building maintenance. However, 25.00% indicated that there is an existing use of IoT in South Africa. Although the majority disagreed, the presence of some affirmative responses supports the view of a slow pace in technology adoption for facilities management, as affirmed by Naghshbandi (2017).

Existing use of FM (AoT-1)

The use of FM software to aid building maintenance has a mean score of 2.47 with a standard deviation of 1.15, ranking 4th. This score indicates that respondents disagree with the notion that FM software is currently used to aid building maintenance in South Africa. The results show that half of the respondents believe there is no use of FM software for building maintenance in South Africa. This finding supports the notion of slow technology adoption in facilities management, as noted by Naghshbandi (2017) and Love et al. (2015).

Existing use of BIM (AoT-2)

The existing use of BIM achieved a mean score of 2.33 with a standard deviation of 1.11. The results indicate that the respondents disagree that there is an existing use of BIM for building maintenance in their organisations. When the percentage responses are grouped into three categories of Yes (Strongly Agree and Agree), No (Strongly Disagree and Disagree) and Neutral, 59.09% of the respondents indicate that there is no use of BIM for the maintenance of buildings. There is, however, the 15.91% of

respondents that indicated that there is an existing use of BIM in FM. This agrees with Love et al. (2015) who stated that in the United Kingdom there is little use of BIM in FM. The results show that BIM holds potential for use in FM as asserted by Rich and Davis (2010). Despite BIM's capability to improve FM (Becerik-Gerber et al. 2012; Naghshbandi, 2017), slow BIM adoption still persists. BIM is quite new to construction professionals (Rich and Davis, 2010) and this is supported by the results of this study.

Existing use of VR (AoT-5)

Table 1 presents the use of Virtual Reality to aid building maintenance. the use of VR has a mean score of 2.31 with a standard deviation of 1.14. This indicates that respondents disagree with the notion that VR is currently used for building maintenance in South Africa. As depicted in Table 1 57.95% of respondents categorise their views as Strongly Disagree and Disagree, opposing the idea of VR was used to aid building maintenance. Overall, these results suggest that respondents do not believe VR is effectively utilised for building maintenance in South Africa. Although VR can enhance facilities management by allowing users to virtually experience the building environment (Akanmu, Olayiwola and Olatunji, 2020), the results support the notion of slow technology adoption, with only 15.91% agreeing that VR is currently used for building maintenance in South Africa.

Barriers to technology adoption

This section discusses the five most significant barriers hindering the wide adoption of building maintenance technology in South Africa and the two least significant barriers. The study categorises responses into Yes (Strongly Agree and Agree), No (Strongly Disagree and Disagree), and Neutral. Approximately 79.55% of respondents (70 out of 88) believe that B-9 (Implementation of new technology requires high capital investments) is a barrier to technology adoption. Only about 9.09% disagree that B-9 is a barrier, while 11.36% are neutral. These results indicate that the high capital investments required for new technology implementation are a significant barrier to technology adoption for building maintenance in South Africa. This finding is supported by Love et al. (2015), who highlight the costliness of technology investments as a barrier. A substantial number of respondents, approximately 76.14%, believe that B-5 (Cybersecurity, such as network hacking) is a barrier to technology adoption for building maintenance. Only 11.36% oppose this notion, and 12.50% are neutral. Therefore, cybersecurity issues are identified as a barrier to technology adoption in building maintenance, which is supported by Jain et al. (2020). They argue that cybersecurity risks, including information theft and misuse, are significant barriers to adopting Internet of Things (IoT) technologies. Further support comes from Redmond et al. (2012), Wong et al. (2014), and Morgan (2014), who all highlight security and safety challenges as barriers to technology adoption.

The high cost of training stakeholders in the use of technology is also a barrier. Wong et al. (2014) and Love et al. (2015) discuss how expensive training can be. In this study, 76.14% of respondents agree that B-8 (Training on the use of new technology is expensive) is a barrier to technology adoption. Conversely, 10.23% disagree that B-8 is a barrier. This indicates that the high cost of training is indeed a barrier to technology adoption for building maintenance. Regarding B-6 (Relevant stakeholders are resistant to change due to uncertainties), 70.45% of respondents consider it a barrier. Only 6.82% reject B-6 as a barrier. This suggests that resistance to change among relevant stakeholders due to uncertainties is a significant barrier to technology adoption for building maintenance in South Africa. Ahmed (2018) also identifies stakeholder resistance to change as a barrier in the literature, aligning with the findings of this study. For B-14 (Lack of involvement of facility managers in the early stages of a project), 45.45% of respondents strongly agree and 25% agree that it is a barrier to technology adoption. Meanwhile, 15.91% are neutral, 5.68% strongly disagree, and 7.95% disagree that B-14 is a barrier. This implies that the lack of involvement of facility managers in the early stages of a project is perceived as a barrier to technology adoption for building maintenance, as supported by the mentioned studies.

Concerning the second least significant barrier, B-12 (It is better to save than to constantly spend on new software, tools, and hardware), a combination of strongly disagree and disagree responses accounts for 19.32%, while strongly agree and agree responses make up 54.55%. With a mean score of 3.55, which falls within the range of ≥ 3.41 and ≤ 4.20 , participants generally agree that B-12 is a barrier to technology adoption for building maintenance. For the least significant barrier, B-4 (Information provided by certain systems such as BIM contains unnecessary details for maintaining a building), 27.27% of respondents strongly agree and 25% agree that B-4 is a barrier. This totals 52.27%

of respondents who view B-4 as a barrier to technology adoption. Conversely, 5.68% strongly disagree and 14.77% disagree that B-4 is a barrier, making a total of 20.45% who do not consider B-4 a barrier. Approximately 27.27% of respondents are neutral on this issue.

Conclusion

The study investigated the adoption of building maintenance technology in South African organisations, focusing on the use of Cloud Computing, GIS, IoT, FM software, BIM, and VR, as well as identifying barriers to the widespread adoption of these technologies. The findings reveal a slow adoption rate for various advanced technologies in building maintenance. Cloud Computing and GIS, while recognised in theory, face limited practical application, with respondents expressing uncertainty about their use. Similarly, the IoT, FM software, and BIM show even lower adoption levels, reflecting a cautious approach to integrating these technologies into maintenance practices. VR also exhibits minimal application, indicating that its potential benefits have not yet been fully realised in the South African context. The study identified significant barriers to the adoption of these technologies. High capital investments required for new technology implementation was a major challenge, with a substantial majority of respondents perceiving it as a barrier. Cybersecurity concerns and the high cost of training stakeholders were also highlighted as significant impediments. Resistance to change among stakeholders and lack of early involvement of facility managers further exacerbate the difficulties in adopting new technologies. Although some barriers, such as perceived excess detail in BIM systems and ongoing expenditure on new software and hardware, were considered less significant, they still contribute to the overall reluctance toward technology adoption.

Recommendations

Based on the findings of this study, specific recommendations are made. To address the barriers of high capital investment and costly training, stakeholders should focus on providing more cost-effective training programs and workshops to demonstrate the long-term benefits of new technologies. Enhanced training can also alleviate resistance by preparing stakeholders with the necessary skills to manage new tools and systems effectively. Additionally, it is crucial to implement robust cybersecurity measures to protect against network hacking and data breaches, which can foster greater confidence in adopting new technologies.

Facilitating early involvement of facility managers and other relevant stakeholders in the project phases is essential. This engagement assists with addressing uncertainties and resistance to change by integrating their insights and concerns into the technology adoption process from the outset. Encouraging a gradual approach to technology adoption can also ease the financial burden associated with high capital investments, providing organisations with the opportunity to scale their investments and evaluate the effectiveness of new technologies over time.

Addressing specific barriers such as excessive detail in BIM systems and ongoing expenditure on new tools is important. Tailoring solutions to these concerns can help overcome resistance and foster a more positive attitude toward technology adoption. Through these strategies, stakeholders and policy-makers can work towards overcoming the identified barriers and facilitate a more widespread and effective adoption of building maintenance technologies in South Africa.

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Building New Realities: Enhancing Quantity Surveying and Architectural Education Through Augmented Reality and Virtual Reality Innovations in South Africa

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Abstract

This study aims to explore the effectiveness of augmented reality (AR) and virtual reality (VR) technologies in enhancing educational outcomes for Quantity Surveying (QS) and Architectural students. It assesses how these technologies improve learning and practical training that will yield work-ready graduates that the industry needs through improved conceptualisation of abstract concepts. This paper uses a systematic review methodology to examine empirical studies focused on AR and VR applications in educational settings within QS and Architectural disciplines. Papers were sourced from academic Google Scholar and research databases, with selection criteria emphasising studies that provide clear outcome measures and robust experimental designs. The findings reveal that AR and VR significantly boost spatial visualisation skills, enhance engagement and understanding of complex surveying data, and provide effective simulation environments that mimic real-world scenarios. Studies consistently show improved test scores and practical skills among students who used these technologies compared to traditional learning methods. While the results are promising, most studies suffer from small sample sizes and short-term implementation, which may not capture long-term learning outcomes and retention. There is also a variance in technology quality and instructional design, which can affect the generalizability of the results. Integrating AR and VR into Quantity Surveying education can lead to more dynamic and interactive learning experiences that are less constrained by physical and logistical limitations. Educational institutions should consider infrastructure and equipment investments and curriculum redesigns to incorporate these technologies effectively. This review provides a consolidated resource for educators and technologists interested in the potential of immersive technologies in educational settings. Most of the strategies and technologies are relevant to South Africa.

Keywords: Augmented Reality (AR), Virtual Reality (VR), Educational Outcomes, Simulation Environments, Curriculum Integration.

Introduction

Training industry-ready graduates and practitioners who can effectively conceptualise abstract concepts continues to be a significant challenge in higher education (HE), particularly in developing countries. This challenge is especially pronounced in the fields of Quantity Surveying (QS) and Architecture, where students must bridge the gap between theoretical knowledge and practical application. While traditional teaching methods, which rely heavily on lectures and 2D drawings, provide a foundation of theoretical knowledge, they often fall short in preparing students for the complexities of modern construction environments. The gap between classroom learning and the practical demands of the industry has become more pronounced with the increasing complexity of projects and the rapid pace of technological advancement.

The advent of Augmented Reality (AR) and Virtual Reality (VR) technologies offers a promising solution to this problem. However, there is limited research that thoroughly examines how AR and VR can be effectively integrated into QS and Architectural education, especially within the context of developing countries like South Africa. Existing studies often focus on developed countries, where access to

technology is less of a constraint, and there is a significant gap in research addressing the unique socio-economic and infrastructural challenges faced by institutions in developing regions.

This paper seeks to address this research gap by exploring how AR and VR technologies can enhance both learning outcomes and practical training in Quantity Surveying and Architecture. The study specifically focuses on the applicability of these technologies within the South African context, acknowledging the distinct socio-economic and infrastructural challenges that impact their integration. Through this exploration, the paper evaluates how AR and VR technologies, when integrated with Building Information Modelling (BIM), can enhance students' ability to conceptualise and apply complex construction concepts, thereby addressing some of the limitations of traditional teaching methods. Additionally, the paper aims to provide actionable recommendations on how to overcome the barriers to adopting AR and VR in QS and Architectural education in South Africa and other developing regions, ensuring that these technologies can be leveraged to produce work-ready graduates equipped for the modern industry.

However, in South Africa and most developing countries, several challenges hinder the widespread adoption of AR and VR technologies. These include large class sizes, high student-to-instructor ratios, and incoming students with diverse levels of preparedness for higher education. Additionally, low levels of technology penetration among students and a lack of access to real-world case studies and projects further exacerbate the difficulty of bridging the gap between abstract concepts and practical design and implementation. These unique challenges make it difficult to directly adopt technological interventions used successfully in developed countries without considering the local context and constraints.

Literature Review

With a focus on teacher-centered methods, traditional teaching methods in education often involve lecture handouts, repeated learning, and note-taking. In this approach, students learn primarily through reading, lectures, and observation, with lecturers taking the lead (Hajirasouli & Banihashemi, 2022). Lord (1999) criticised this strategy, pointing out that students can find it difficult to remember the knowledge they have learnt and to use it to solve issues in new ways (Lord, 1999; Luo & Mojica Cabico, 2018). Traditional approaches in the domains of architecture and construction (AC) highlight the creation of core, well-defined knowledge and rely on manuals or standard operating procedures for knowledge transmission.

While explicit information is unquestionably necessary for the next generation of industry practitioners to have experiential knowledge, which is often acquired over years of experience, may be especially important when existing industry veterans retire from the industry (Hartless et al., 2020). Despite being shown to be inefficient, outdated, and ineffective, traditional teaching techniques are still frequently used in many educational institutions (Hajirasouli & Banihashemi, 2022). The importance of learning in a blended learning environment that combines conventional and technology-based learning and teaching approaches shows that by using technology-based pedagogical tools into traditional teaching techniques, instructors can effectively address concerns and problems associated with traditional learning for Architecture and Construction (AC) (Hajirasouli & Banihashemi, 2022). Immersive technologies, including virtual reality (VR) and augmented reality (AR), have gained recognition as effective supplementary teaching tools that can effectively address the shortcomings and inadequacies of traditional teaching methods. (Hajirasouli & Banihashemi, 2022).

In the construction industry, communication is crucial, and 2D drawings are still utilised despite their limitations in properly portraying 3D objects. The transition to three-dimensional (3D) modelling, especially with Building Information Modelling (BIM), improves understanding but presents obstacles since it requires costly equipment and specialised knowledge. Even with these developments, 2D drawings are still widely used, and new technologies like Augmented Reality (AR) and Virtual Reality (VR) are predicted to drive the use of 3D modelling in the industry even further (Sung Joon Suk et al., 2017).

With the help of 3D model images created by AR, students' understanding of construction elements is increased. The difficulty in quantifying is that the construction elements are illustrated in 2D drawings. Furthermore, most students lack sufficient field experience that would enable them to comprehend the entirety of the structures' building parts and conceptualise abstract concepts (Sung Joon Suk et al., 2017). Students' comprehension of construction elements can be cultivated through field tours to

construction sites. However, planning several field trips for a course within a semester might be challenging. Possibly, some of the drawings used for projects that students go on field trips differ from those supplied in class. With AR, students can see augmented reality images using their mobile device with ease thanks to the quick development of AR software (Sung Joon Suk et al., 2017). Students can get a better grasp of the building aspects required to provide an accurate cost estimate by aligning AR photos with 2D drawings as reading and understanding construction drawings and concepts is a fundamental part of preparing students to enter the construction industry (Sung Joon Suk et al., 2017).

Khan et al. (2021) looked at the use of virtual reality (VR) and building information modelling (BIM), creating a workflow model that took students input into account. The research highlighted how virtual reality (VR) improves traditional learning techniques by enhancing immersive simulations and experience learning, enabling the exploration of challenging or dangerous site areas, and adapting to the demands of the learner. Khan et al. elaborated more on the study about the increasing need for innovative digital classroom learning solutions following the COVID-19 pandemic. The study showed that (VR) is becoming more accessible and economical, and that it may eventually be the standard teaching tool for architecture, engineering, and construction (AEC) (Onur Dursun & Qabshoqa, 2024).

In this paper, we report on a comprehensive and systematic literature review of the strategies used to incorporate VR and AR into QS and Architectural education. The unique contributions of this paper are in its evaluation of the outcomes of the interventions and their relevance to the context of South Africa and developing countries. This is important because the geographical, cultural technological, socio-economic and educational context may not allow direct transfer from developed countries' contexts.

Research Methodology

This paper adopts a systematic review approach, following the PICO framework (Population, Intervention, Comparison, Outcome) to guide the formulation of research questions (Eriksen et al., 2018). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were employed to ensure a structured and comprehensive selection of literature and a transparent analysis of the research findings (Eriksen et al., 2018). The goal is to critically examine how AR and VR technologies can enhance Quantity Surveying (QS) and Architectural education, particularly within the socio-economic and infrastructural constraints of South Africa.

Research questions

- How can the conceptualisation of abstract concepts within Quantity Surveying and Architectural education be improved while strengthening collaborations within South African higher education?
- How can AR and VR be integrated to improve the quality of Quantity Surveying and Architectural Education within the context of South Africa?
- What are the alternative strategies/approaches of integrating experiential and practical learning in QS and Architectural Education?
- What outcomes, challenges and opportunities are there for integrating AR and VR into QS and Architectural Education?

Literature selection and analysis

To address these questions, a systematic search for relevant literature was conducted using academic database Google Scholar, to ensure comprehensive coverage. The search phrases used included: "Challenges of implementing AR and VR in the built environment," "Integrating VR and AR in the built environment," and "QS and Architecture BIM education." The initial search in Google Scholar yielded 164 papers, while direct searches of Scopus and Web of Science provided an additional 147 papers.

After eliminating duplicates, abstract screening was conducted, resulting in the exclusion of papers that did not focus on QS and Architectural education. This process left a total of 63 relevant articles. Further full-text screening led to the selection of 45 papers for detailed critical review. Additionally, backward and forward bibliographic analysis was performed on the selected papers to identify key citing and cited works. This final stage of the selection process resulted in a total of 30 highly relevant papers being included in the study.

The inclusion criteria required that studies focus specifically on the use of AR and VR in QS or Architectural education, present clear quantitative or qualitative outcomes such as student test scores, skill improvements, or feedback, and be based on empirical research. Studies that lacked robust experimental design or relevant context (e.g., those based solely on theoretical discussions without practical implementation) were excluded from the review.

Data extraction and analysis

Once the final papers were selected, a comprehensive analysis was conducted to extract key information regarding the strategies used for integrating AR and VR, the challenges and opportunities identified, and the outcomes achieved. Particular emphasis was placed on identifying case studies that demonstrated successful use of AR and VR technologies in educational settings. The analysis also considered the geographical transferability of these approaches, especially their relevance to South Africa and other developing regions where access to technology may be limited.

The review identified a range of both subjective outcomes (such as student engagement and feedback) and objective outcomes (such as test scores and practical skill assessments). **Geographical analysis** was conducted to explore whether strategies used in developed countries could be feasibly applied in South Africa, given the distinct infrastructural and socio-economic challenges faced by the region.

Findings

The integration of AR and VR technologies into educational environments has shown transformative potential in enhancing student learning outcomes. Several case studies and literature reviews demonstrate significant improvements in areas such as **student engagement, collaboration, visualisation, and communication skills**. For example, VR was successfully integrated into design projects for final-year architectural students, leading to increased interest and engagement. Similarly, research conducted across various countries, including the United States, United Kingdom, and Sri Lanka, highlights how AR and VR foster improved comprehension of complex concepts. These technologies provide immersive experiences that enable students to interact with three-dimensional models, thus enhancing their understanding of abstract structures. In addition to their impact on learning, AR and VR also improve students' motivation and their ability to collaborate on projects. Overall, the findings underscore the value of AR and VR in transforming traditional teaching methods and better preparing students for real-world challenges.

Case uses of AR and VR

Several use cases of AR and VR and literature reviews were identified from literature along with their obtained outcomes. These are summarised in Table 1, showing that outcomes such as student engagement, interest in learning, improved interaction and collaboration, improved visualisations, improved motivation, and communication skills were achieved.

Table 1: Summary of the cases of VR and AR integration used and reviewed

Reference	Location	Summary of Methods	Outcomes
Horne et al 2006	United Kingdom	Phased Integration: Integrated VR technology into the curriculum of built environment students at Northumbria University. Case Study: Implemented VR in a design project for final-year Architectural Technology students. Analysis: Evaluated the process and results of VR implementation, including challenges and acceptance by staff and students	Student Engagement: Increased interest from students and industry in VR applications. Model
Horne et al 2008	United Kingdom	Qualitative research method was used among staff and tutors the Built Environment on perception of VR incorporation into the curriculum through CAD and 11 interviews were conducted and total projects started was 79 and 47 reached completion of VR being implemented.	Improved awareness of VR amongst staff and Tutor and better module delivery.
Dickey 2005	United States of America	Review: This paper reviewed the design affordances and constraints of two 3D virtual reality worlds used as interactive learning environments.	Improved interaction and

		Comparative Analysis: Compares different features and functionalities of the two 3D virtual reality worlds in educational contexts.	visualisation of concepts.
(Onur et al, 2024)	United Kingdom	The study uses BIM with final year students. Using qualitative and quantitative data collection it explores the use 2D and VR to evaluate learning improvement.	Improved motivation and comprehension.
(Weerasooriya et al, 2023)	Sri Lanka	This is a literature review that critically analyses prior empirical works to assess the impacts of cyber-physical systems (CPS) in enhancing student learning.	Enhanced collaboration and communication. Reduction of errors.
(Palis et al, 2022)	Sarawak	Study investigates the challenges faced and methods used in integrating BIM into curriculum. Literature reviews and questionnaires of university respondents.	Identified challenges and strategies for BIM integration.

Strategies of integrating AR and VR

Weerasooriya et al. (2023), cite the use of testbeds as part of training to improve student learning. Such testbeds can be used as experiments and projects in both traditional and project-based learning approaches. Despite the often-prohibitive costs and skills requirements, these technologies are realisable in developing economies.

Palis et al. (2022) identified collaborations between academia, industry and accreditation bodies; stand-alone BIM courses; instructor upskilling and; online learning platforms as some of the strategies to integrate BIM and overcome challenges. Multiple-helix collaborations remain a challenge in South Africa and most countries. Curriculum related strategies on the other hand are currently practiced and applicable to the South African context.

A scoping review conducted by Oje et al. (2023) highlights problem-based learning, collaborative learning, guided inquiry as methods of incorporating VR into learning. They focus on learning theories such as Cognitive Theory of Multimedia Learning (CTML) and Cognitive Load Theory (CTL), based on limited human memory capacity to advocate for the careful balance of visual and verbal material in content and students' freedom to choose as a good approach. They also cite the coherence principle for optimising students' interest by eliminating irrelevant albeit interesting content, as well as the pre-train principle that proposes the familiarisation of students to relevant jargon prior to exposing them to multimedia. The Segmentation principle which proposes student chosen small segments and pace are also encouraged. Finally, the paper recommends that the selection of multimedia should consider affective components of multimedia as evoked emotions influence learning. Mania et al. (2021) summarise elements of pre-learning and extend affective considerations to include social, cultural and religious factors (in-learning). Cognitive learning considerations to allow students to build on their existing knowledge and collaborative learning are also encouraged in the integration of VR, AR and BIM.

Further learning theories are explored by Radianti et al. (2020) towards enhancing the effectiveness of VR and AR technologies in learning. These are *behaviourism*, which advocates repetition and reinforcement to promote learning; *cognitivism* which encourages that pre-existing knowledge of students should be factored and leveraged in selection and use of VR and AR technologies; *constructivism*, which motivates for active learning and allowing students to construct their own interpretations and organisation of knowledge; *experientialism*, through stages of experiential learning from experience, observation, reflection, abstract conceptualisation and new situations and; *connectivism*, through allowing students to form their own knowledge connections.

A further dimension of VR and AR explored integration concerns the elements of interaction included in the AR and VR tools or experiences. These are summarised in Figure 1 with their reported frequency of inclusion in educational experiences. It is however not clear how efficient each of these are in learning improvement.

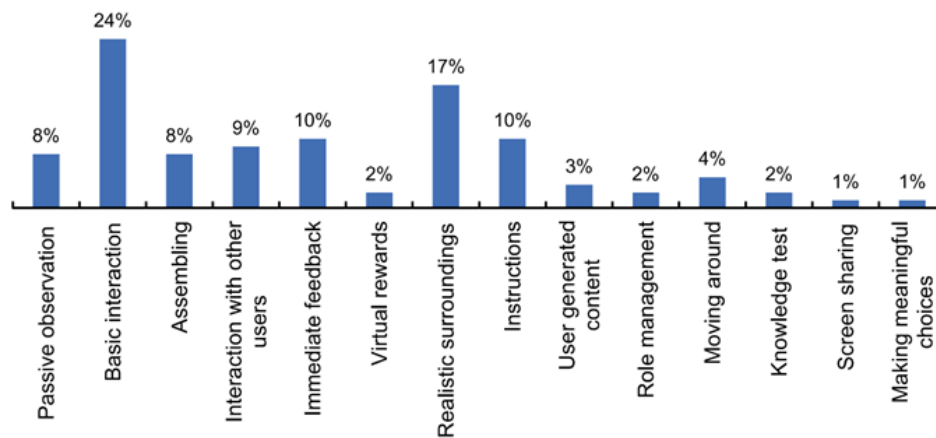


Figure 1: Elements of AR and VR experience included in educational design, with their percentage frequency of use (Radianti et al., 2020).

Tanaka (2019), cites the 79% prevalence of project-based learning, 11% peer assessment and 5% for synchronous sharing and issue-based learning each. These methods are practiced in most universities in South Africa and globally. Challenges include large class sizes, costs of project equipment and balancing content load with practical exposure.

Opportunities and challenges of integrating AR and VR

Palis et al. (2022) focused on identifying challenges of integrating VR in QS education. They identified 20 challenges across multiple domains of curriculum, knowledge and skills and resourcing. The challenges were lack of accreditation criteria, multidisciplinary content, curriculum change, literary resources, choice of tools, instructor expertise, cost of tools, administration of tools, IT infrastructure and internet connectivity, management sponsorship and government initiatives and physical space constraints among others. Ebekozi and Aigbavboa (2022) cite similar challenges and include resistance to change.

Limitations in the research reported include small sample sizes. Many studies involved small sample sizes, limiting the generalizability of the results (D'Angelo et al., 2014; Allcoat & von Mühlenen, 2021; Aroba, 2024). Secondly, most studies focused on short-term outcomes without assessing long-term learning impact and retention (Allcoat & von Mühlenen, 2021; Aroba, 2024; Gurevych et al., 2021; Grant, 2009; Borrego, 2015). Third, variability in technology and design - differences in the quality of AR and VR technologies and instructional designs can affect the consistency and applicability of results (Aroba, 2024; Gurevych et al., 2021; Enzai et al., 2021; Grant, 2009; Borrego, 2015).

Outcomes of AR and VR

Outcomes of integrating AR and VR vary based on the intended use and measurements of improvement performed in different studies. Commonly subjective measures such as students' opinions or feedback are used, as well as quantitative measures such as student grades in courses. Subjective measures often focus on student collaboration, communication, visualisation skills, creativity, engagement and overall satisfaction. Table 2 shows some of the outcomes from Tanaka (2019).

Table 2: Learning outcomes of AR and VR (Tanaka, 2019)

Inductive Categories	Sub-Categories	Quantity	Sample Research
General pedagogies	Improve students' learning interest	7	[39]
	Improve students' academic performance.	6	[24]
	Motivate students more	4	[47]
	Satisfaction of students with the course	4	[48]
	Effective tool in traditional pedagogical settings	4	[36]
	Improve students' course participation	3	[46]
	Helpful for knowledge integration and internalization	1	[40]
	Help students communicate with course contents in the classroom	1	[39]
	Improve communication between teachers and students	1	[37]
Domain-specific learning	Increase graphic competencies and spatial skills	2	[47]
	Great potential to be applied in construction projects	1	[25]
	Helpful instructional techniques to learn structural analysis	1	[49]
	Improve students' understanding of building roof components	1	[50]
	Help students to expand their thinking in building-design processes	1	[17]
	Improve the clarity of students' 3D perception	1	[37]

Our review further identified several key benefits of AR and VR in education:

- **Enhanced Spatial Visualisation:** AR and VR technologies significantly improve students' ability to visualise and understand spatial relationships and complex structures (Allcoat & von Mühlenen, 2021; D'Angelo et al., 2014; Aroba et al., 2023; Borrego, 2015).
- **Increased Engagement:** These technologies boost student engagement and motivation by providing interactive and immersive learning experiences (Aroba, 2024; Gurevych et al., 2021; Enzai et al., 2021; Borrego, 2014). These should be coupled with pedagogical approaches such as pre-training, while being mindful of cognitive loading.
- **Improved Understanding:** AR and VR enhance comprehension of complex surveying data and architectural designs (Aroba, 2024; Enzai et al., 2021; Aroba et al., 2023; Grant, 2009; Borrego, 2015). Minimisation of irrelevant content helps balance content volume and improve student interest.
- **Effective Simulations:** VR, in particular, offers realistic simulation environments that mimic real-world scenarios, enhancing practical training (D'Angelo et al., 2014; Allcoat & von Mühlenen, 2021; Aroba et al., 2023).

The South African context - practical implications

Integrating AR and VR into Quantity Surveying education can transform traditional learning methods, for improved student learning. Educational institutions should consider multiple levels at which interventions are implemented.

In South Africa, the standardisation and accreditation of QS and Architectural programmes is the responsibility of SACQSP (South African Council of Quantity Surveying Profession) and SACAP (South Africa Council for the Architectural Profession). The educational inputs, processes and outcomes and accreditation criteria should be updated to emphasise the integration of AR and VR technologies into programmes and curricula. Figure 2 shows an educational design framework with which interventions should occur.

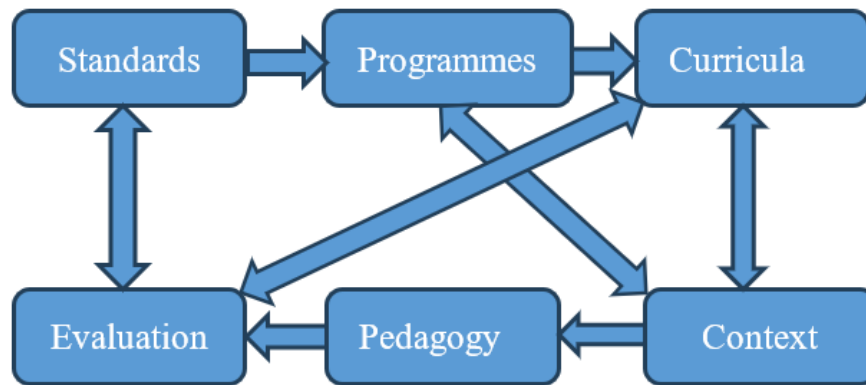


Figure 2: Educational design framework

Curriculum redesign and transformation needs to incorporate AR and VR effectively (Aroba, 2024; Enzai et al., 2021; Aroba et al., 2023; Grant, 2009; Borrego, 2015). Several approaches have designed specialised stand-alone AR and VR courses as part of the curricula, while others have opted to integrate AR and VR as part of mainstream courses. In the latter, projects and experiments are some of the methods used.

Once the integration at curriculum level and content level is achieved, pedagogical choices should be made to improve student engagement, balance cognitive loading, socio-economic backgrounds as well as other learning theories (Oje et al., 2023).

Universities must increase infrastructure investments to support AR and VR technologies (Aroba, 2024; Gurevych et al., 2021; Enzai et al., 2021; Borrego, 2015). This is especially important in South Africa where most students cannot individually afford the AR and VR equipment. Central resources must be provided.

Majority of educators in QS and Architectural programmes do not possess skills in AR and VR technologies as well as skills to manage and administer them. Educators require training to effectively use AR and VR technologies in their teaching (Aroba, 2024; Gurevych et al., 2021; Enzai et al., 2021; Grant, 2009; Borrego, 2015). This is not difficult in university settings as Technology departments such as Computer Science, Electronics and Information Technology in the same or other institutions can offer such training at low or no cost.

Discussion

This study provides critical insights into the integration of Augmented Reality (AR) and Virtual Reality (VR) technologies in Quantity Surveying (QS) and Architectural education, particularly within the context of South Africa. The findings underscore the transformative potential of these technologies in enhancing educational outcomes, while also identifying key challenges and opportunities. The successful integration of these technologies also requires a careful selection of pedagogies. These include strategies that balance cognitive overload, emotional cues of students. Background of students and backgrounds to be taken into consideration to ensue successful implementation of AR and VR into the curriculum

Among other methods, AR and VR technologies have proven to be effective tools for improving the conceptualisation of abstract concepts in QS and Architectural education. These technologies facilitate enhanced spatial visualisation, allowing students to interact with complex 3D models that are otherwise challenging to grasp through traditional 2D drawings. This ability to visualise and manipulate digital models in a virtual space significantly aids in understanding complex structures and spatial relationships, thus bridging the gap between theoretical knowledge and practical application. (Allcoat & von Mühlenen, 2021; Khan et al., 2021).

The successful integration of AR and VR in South African higher education requires a multifaceted approach as articulated in this section. These include the formulation of standards and graduate outcomes or attributes that emphasise competencies in AR and VR; design of courses and content in courses that exposes students to these technologies; pedagogical innovations based on learning

theories such as constructivism, cognitivism, behaviourism among others to design delivery and assessment methods using approaches such as project-based, problem-based, collaborative and guided inquiry learning. These pedagogical approaches should also consider cognitive loading of students as well as affective elements of multimedia (Oje et al., 2023). In South Africa, and most geographies, the integration of AR and VR requires significant investment in equipment and infrastructure, upskilling of educators and management support as well.

Traditional methods such as 2D drawings and physical models remain prevalent but are increasingly supplemented by blended learning approaches that integrate technology-based tools. Field trips and real-world case studies, while valuable, are often constrained by logistical limitations that are influenced by large number of students. AR and VR present innovative alternatives, offering immersive, interactive simulations that replicate real-world scenarios within a controlled environment, thus enhancing experiential learning without the associated constraints. (Sung Joon Suk et al., 2017; Onur Dursun & Qabshoqa, 2024).

The integration of AR and VR in QS and Architectural education has yielded several positive outcomes such as enhanced Learning Outcomes and this is highlighted in empirical studies that consistently demonstrate that students exposed to AR and VR technologies exhibit improved test scores, enhanced practical skills, and better comprehension of complex data and abstract concepts in Quantity Surveying and Architecture studies compared to those taught through traditional methods. (D'Angelo et al., 2014; Enzai et al., 2021; Borrego, 2015). Simulation Environments through VR, in particular, provides realistic, immersive simulation environments that mirror real-world conditions of site and construction projects, offering students practical experience in a safe and controlled setting without the hassle taking large unmanageable numbers of students to site. (D'Angelo et al., 2014; Enzai et al., 2021; Borrego, 2015).

However, the findings also highlight significant challenges such as sample size and Implementation duration. Many studies reviewed suffer from small sample sizes and short-term implementation, limiting the generalizability of the results and their ability to capture long-term impacts on learning and retention. (D'Angelo et al., 2014; Allcoat & von Mühlennen, 2021; Aroba, 2024). Technology and Design Variability also proved to be a challenge as the variability in AR and VR technology quality and instructional design presents a challenge to standardising these tools across different educational settings (Gurevych et al., 2021; Enzai et al., 2021; Grant, 2009). This inconsistency can affect the reliability of the outcomes and complicate the integration process.

Despite these challenges, the opportunities for further development and integration of AR and VR in QS and Architectural education are substantial as advancement in Technology as AR and VR technologies continue to evolve and become more accessible, they are poised to play an increasingly central role in education, particularly in disciplines requiring high levels of spatial awareness and practical application as is the case with Quantity Surveying and Architectural studies. (Aroba, 2024; Onur Dursun & Qabshoqa, 2024). Curriculum Integration also has significant potential to further embed AR and VR technologies within the curriculum as it opens up to having shared modules between Quantity Surveying and Architectural studies, transforming the educational landscape and making it more multidisciplinary which better prepares students for the demands of the modern construction industry where they work in a team made up of different professions (Palis et al., 2022; Weerasooriya et al., 2023).

Conclusion

A systematic literature review was conducted, revealing that AR and VR technologies hold significant potential to enhance educational outcomes in both Quantity Surveying and Architecture. By improving spatial visualisation, student engagement, and comprehension of complex concepts, these technologies equip students with the skills needed to address real-world challenges. However, to fully harness the benefits of AR and VR, educational institutions must address existing limitations, including investing in necessary infrastructure, curriculum redesigns, and educator training. This paper contributes to the ongoing discourse on the role of innovative technologies in education, offering valuable insights for educators, technologists, and policymakers.

The successful integration of AR and VR requires a thoughtful selection of pedagogical approaches, informed by established learning theories such as Cognitive Load Theory (CLT), to ensure the technologies are used effectively. Additionally, the socio-economic context of regions like South Africa

must be considered, as many students lack access to the necessary equipment, underscoring the need for centralised resources within institutions. Professional development for educators is also critical, as many lack the necessary skills to integrate AR and VR into their teaching practices effectively.

Several challenges remain, including the lack of standardisation, limited infrastructure, insufficient management support, and the need for better IT administration and educational resources. Resistance to change and the high costs of AR and VR technology further complicate widespread adoption. In the South African context, targeted interventions are required at all levels to overcome these barriers and ensure that AR and VR technologies can be successfully incorporated into QS and Architectural education, ultimately enhancing the quality of graduates entering the workforce.

Recommendations

To fully realise the potential of AR and VR technologies in education, institutions should prioritise their integration into curricula, particularly in Quantity Surveying and Architecture. These technologies can enhance learning outcomes by improving visualisation, spatial awareness, and practical skills, particularly in multidisciplinary courses such as Quantities and Documentation, where collaboration between architects and QS professionals is essential. This multidisciplinary approach has been advocated by Aroba (2024), Gurevych et al. (2021), Enzai et al. (2021), and Borrego (2015), who emphasise the role of AR and VR in fostering cross-disciplinary collaboration and improving student engagement.

Investment in adequate infrastructure is essential to support the effective use of AR and VR technologies, especially in the South African context where socio-economic factors limit individual access to these tools. Aroba (2024), Gurevych et al. (2021), Enzai et al. (2021), and Borrego (2015) highlight the importance of institutional infrastructure to overcome these barriers, enabling broader access to AR and VR resources such as BIM. Without sufficient institutional investment, students in developing regions may not benefit fully from these innovations due to the prohibitive cost of equipment.

Additionally, educator training is crucial to ensure that lecturers are equipped with the skills necessary to maximise the potential of AR and VR technologies. This includes proficiency with software such as BIM, which is integral to both QS and Architectural education. Aroba (2024), Gurevych et al. (2021), Enzai et al. (2021), Grant (2009), and Borrego (2015) stress the need for ongoing professional development to ensure that educators can effectively integrate these tools into their teaching practices and adapt to rapidly evolving technological advancements.

In conclusion, the successful integration of AR and VR technologies requires a holistic approach, addressing infrastructure, curriculum development, and educator training. By doing so, educational institutions can ensure that students are better prepared to meet the demands of the modern construction industry, particularly in contexts where access to cutting-edge technology is limited.

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Closing the Loop: Exploring the Quantity Surveyors' Role in Promoting Circularity at the Pre-contract Stage

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Abstract

The construction industry is one of the biggest polluters and consumers of raw materials, yet it serves as a major socio-economic driver in South Africa. The advent of the circular economy (CE) as a framework for eliminating waste and minimising resource consumption offers a viable solution. However, its integration by quantity surveyors at the pre-contract stage has been insignificant. Therefore, this paper aims to evaluate how quantity surveyors can integrate circularity at the pre-contract stage as a mechanism to address the prevailing environmental challenges within the sector. The study employed a qualitative research methodology using an inductive approach to construct theory. Data was collected through in-depth interviews with professionally registered quantity surveyors in the Eastern Cape province. The findings suggest low awareness of circularity among quantity surveyors and limited application at the pre-contract stage. The findings also reveal that quantity surveyors can leverage decision-making, cost and value-related roles to promote its integration at the pre-contract stage. The study's theoretical framework was constrained by a scarcity of related literature, particularly within a South African context. The findings can inform curricula within higher education and continuous professional development (CPD) to capacitate quantity surveyors with the necessary skills and competencies to adequately respond to the evolving demands of circularity within the construction industry. Additionally, existing procurement policies within the sector can be amended to include key tenets of CE as a strategy to accelerate its integration within the sector. Interventions for promoting circularity through quantity surveying roles are revealed at the pre-contract stage.

Keywords: Circular Economy, Sustainability, Quantity Surveyor, Pre-contract, Construction Industry.

Introduction

The construction industry must prioritise innovative and sustainable solutions that reduce its environmental impact, whilst also increasing its profitability (Wijewansha et al., 2021). The circular economy (CE), which is “restorative and regenerative by design”, offers an alternative to the current “take-make-waste” linear model, by promoting the “regeneration of materials, products and components” in a manner that retains their value through its 3R's of “reduce, reuse and recycle”, (Sverko Grdic et al., 2020). When integrated into the construction industry, CE can facilitate sustainable construction practices (Wijewansha et al., 2021), by significantly reducing the amount of construction and demolition waste (CDW), and thereby also aligning it to the United Nations Sustainable Development Goals (SDGs), (Asante et al., 2022). Within a South African context, sustainable construction practices remain scarce, despite the sector's critical importance in facilitating socio-economic transformation (Marsh et al., 2020). Marsh et al., (2020), attributes this to limited awareness amongst stakeholders in the industry. Therefore, sustainable concepts such as CE need to be prioritised in the South African construction industry to effectively address and mitigate the prevailing environmental challenges within the sector (Wijewansha et al., 2021).

The pre-contract stage is arguably the most crucial phase of a building's lifecycle (Foster, 2020). This is because most of a project's decisions made at this stage have a profound impact on all other lifecycle stages (Bragança et al., 2014). Therefore, professionals in the built environment have an integral role to play in the integration of circularity at the pre-contract stage, through the conversion of sustainable objectives into clear and actionable project initiatives (Adams et al., 2017). Among these BE professionals, the quantity surveyor is perhaps the best suited to facilitate CE integration at the pre-

contract stage (Victor et al., 2022). This is because the profession integrates various elements from other disciplines with its core functions (Victar et al., 2022), thereby equipping quantity surveyors with the necessary skills needed to be able to effectively respond to the demands of integrating CE at the pre-contract stage (Chamikara et al., 2020). Furthermore, quantity surveyors hold a significant sway on project cost, which could be leveraged to promote CE at the pre-contract stage (Morrison et al., 2022). Notably however, minimal attention has been given as to how quantity surveyors can promote CE in the built environment (BE), thus necessitating the need for a further inquiry (Victar et al., 2022).

Therefore, this study aimed to address environmental concerns in the South African construction industry by investigating quantity surveyors' understanding and awareness of circularity and its key tents, and by examining how their pre-contract roles can be leveraged to advance CE integration within the sector. Specifically, the research identified challenges such as low awareness of circularity among quantity surveyors. By offering insights into these challenges and the associated opportunities, this study helps fill a significant gap in the literature regarding the role of quantity surveyors as key proponents of sustainable construction, particularly within a South African context (Wijewansha et al., 2021).

Literature Review

Circular economy and the built environment

The circular economy provides a “closed loop” flow of materials that serves to minimise or eliminate waste and extend the useful life of products and materials (Hanif, 2022). This promotes long-term sustainability by minimising resource depletion and waste generation (Wright et al., 2019). CE is an antonym of the traditional linear “take, make and dispose model” (Wright et al., 2019). The concept has several definitions; however, most scholars agree that it is a combination of three overarching mechanisms of “reduce, reuse and recycle” (Ghisellini et al., 2016). Within the built environment, Benachio et al., (2020) defines CE as; *“The use of practices, in all stages of the life cycle of a building, to keep the materials as long as possible in a closed loop, to reduce the use of new natural resources in a construction project”*. The concept of reduce aims to decrease the inputs that are required in the production process (Ghisellini et al., 2016), and can be applied at the pre-contract stage by adopting techniques that remove waste from the project design (wahyu & Wibowo, 2020). The reuse principle aims to extend the useful life of products before either replacing or repurposing them for a different use (Ma et al., 2014) , and presents the most viable option for waste management (Wijewansha et al., 2021). The recycle principle refers to the recovery of materials with residual and useful value resulting in a reduction in the amount of waste produced (Birat, 2015). However, recycling is considered less sustainable than other CE principles because it consumes more resources such as energy and labour inputs (Stahel, 2013). A transition from a linear to a circular economy will not be realised until circular value is in cooperated throughout all the life cycle stages of a project (Akhimien et al., 2021). According to Hopkinson et al., (2019), the construction industry has a tremendous potential for CE value creation. Similarly, Smol et al., (2015) and Govindan & Hasanagic, (2018) also observe that the construction industry can benefit from CE in a broader context that ensures resources are optimised and waste production reduced.

Circularity principles at the pre-contract stage

According to Wijewansha et al., (2021), CE can be implemented cost effectively at the pre-contract stage as compared to other life cycle stages of a project. However, few studies have so far explored how circularity can be incorporated at pre-contract, considering that it is the most ideal stage to implement sustainability (Gervásio et al., 2014). Furthermore, most critical project decisions are determined at the pre-contract stage (Bragança et al., 2014). Therefore, incorporating circularity at the pre-contract phase facilitates its easy integration across all other lifecycle stages of a project. Basbagill et al., (2013) observes that decisions made at the pre-contract stage have a direct relationship with the sustainability of built facilities. Moreover, a significant proportion of project costs are assigned at pre-contract, making it the ideal stage to incorporate circularity within the construction industry (Wijewansha et al., 2021). The 3R principles of CE have been expanded over time to include other ancillary principles (Çimen, 2023). For instance, Wijewansha et al., (2021) finds that an expanded 6R principles of CE could be implemented at the pre-contract stage. Benachio et al., (2020), undertakes a systematic review of 45 articles of CE within the construction industry and highlights 6R principles as being applicable at

the pre-contract stage. Similarly, Asante et al., (2022) finds that only four of the 6R principles can be implemented at the design stage, which moves away from Çimen, (2023) findings, who highlights 10R principles as being applicable at the pre-contract stage. From the foregoing, it can be inferred that the core 3R principles of CE, remain highly relevant in the concept's ability to effectively address the prevailing environmental challenges within the sector.

The pre-contract roles of the quantity surveyor vs circularity

The involvement of the quantity surveyor at the pre-contract stage helps to connect the design to cost, resulting in a well-balanced design that maximises value for the client (Morrison et al., 2022). Victar et al., (2022) highlights, "Measurement and Quantification, Cost Control, Cost Planning, Feasibility Studies, Value Engineering, Cost Estimation, Preliminary estimation, Tender Process, Procurement Advise, Contract Administration, Construction Planning, Life Cost Analysis, Cost benefit analysis", as applicable pre-contract roles of the quantity surveyor. Similarly, Eadie et al., (2013) identified "Preliminary cost estimating, Procurement advice, cost planning, measurement of quantities, preparation of bills of quantities and bidding" as core functions of the quantity surveyor at the pre-contract stage. Notably, Chamikara et al., (2020) accentuates "cost planning" as an important pre-contract QS role, and "procurement advise" as a critical function that improves profitability, minimises unnecessary costs, reduces delays, and expedites supply chain activities. Alias et al., (2014) further argues that "cost planning" is the most essential role of the quantity surveyor at the pre-contract stage. According to Munaro et al., (2020) it is important to discuss and integrate circularity at the planning phase, rather than at the end-of-life stage, because it facilitates better and more informed decision making. However, Morrison et al., (2022) argues that there is still a deficiency of adequate information in this field, evidenced by a lack of existing literature discussing how the quantity surveyor can effectively leverage their pre-contract roles to influence the integration of CE in the construction industry.

The pre-contract stage presents quantity surveyors with a favourable opportunity to incorporate circularity in the construction industry, through their influence on cost which drives material and design decisions (Morrison et al., 2022). According to Habibi Parsmodir et al., (2014) a study found "cost control" and "cost planning" as the pre-contract roles that could highly contribute to a reduction in construction waste. In addition, the respondents also strongly agreed that "feasibility studies", "sustainability advisor", "risk management" and "value engineering" were important quantity surveying roles that could facilitate CE at the pre-contract stage (Victar et al., 2022). Contrastingly, Morrison et al., (2022) found that none of the qs pre-contract roles could be supportive of CE, but rather it should be the client's responsibility to drive CE in the construction industry. Chamikara et al., (2020) highlighted important skills that quantity surveyors should possess to promote sustainability within Sri Lanka's construction industry. The competencies identified were "value management, life cycle assessment, whole life costing, lean principles, supply chain management, reuse of buildings, BIM, embodied carbon analysis, factory-based construction, reuse of buildings and materials and energy analysis". CE plays an integral role for the achievement of sustainability (Geissdoerfer et al., 2017), and therefore it is important that quantity surveyors' competencies at the pre-contract stage align with this perspective.

Research Methodology and Method

This study was an exploratory inquiry to examine the influence quantity surveyors would have in promoting CE at the pre-contract stage. Exploratory studies are valuable when exploring novel or underexplored research areas (Myers, 2019). The study adopted an interpretivism philosophy that suggests reality cannot exist independent or separate of the meanings assigned to them (Tracy, 2019). Primary data collection occurred through in-depth qualitative interviews. Qualitative interviews provide a robust and nuanced methodology that is essential for understanding and interpreting a person's social reality, (Ritchie et al., 2014). Qualitative research methods tend to be exploratory by design, and often employ non-probability sampling techniques, which gives the researcher a measure of subjectivity on the appropriateness of a sample to be included in a research inquiry (Saunders et al., 2016). Purposive sampling was used to identify and enrol participants into the study, drawn from the target population comprising of professionally registered quantity surveyors based in the Eastern cape, with at least 5 years of construction experience. Data was collected until saturation, which is the point where data becomes repetitive and redundant, and no longer yields any new insights (Ritchie et al., 2014). According to Saunders et al., (2016), a sample size of between 4-12 participants is well suited to facilitate qualitative data collection to a point of saturation.

The collected data was analysed through inductive thematic analysis facilitated by ATLAS.ti v23, a computer-aided qualitative data analysis software (CAQDAS) that documents and organises the analysis process (Saunders et al., 2016), to ensure accountability and robustness of the analysis process (Silver and Lewins, 2014). The analysis process followed Braun and Clarke, (2013) approach to thematic analysis, which entailed transcribing the audio files verbatim, followed by an initial review of the transcripts to establish familiarity and correct any potential errors in the transcripts. This was followed by a first round of open coding, where relevant codes were assigned to quotations in the data. The second round of coding involved merging and grouping similar codes under categories and thereafter organising similar categories under overarching themes to inform the narrative of the research. To further enhance the credibility and dependability of the analysis process, excerpts from the literature review were combined with relevant quotations and codes (Silver and Lewins, 2014).

Results and Discussion

Responses

Seven participants responded positively and were able to be successfully enrolled in the study, aligning with Saunders et al. (2016)'s recommendation of 4 to 12 participants. Data collection continued until saturation was reached.

Profile of respondents

To ensure both relevance and reliability of the research findings, responses were sought from study participants who had extensive experience in the construction industry and held senior positions within their organisations, as shown in Table 1. Accordingly, Chamikara et al. (2020) posits that respondents with more than ten years of experience help to enhance the robustness and applicability of research findings.

Table 1: Respondents profile

Participant Ref	Designation	Qualification	Mandatory Criteria			Experience
			A1	A2	A3	
P1	Director	BSc:(Hons) Quantity Surveying	✓	✓	✓	13 years
P2	Senior Quantity Surveyor	BSc:(Hons) Quantity Surveying	✓	✓	✓	19 years
P3	Director	BSc:(Hons) Quantity Surveying	✓	✓	✓	10 years
P4	Director	BTech: Quantity Surveying	✓	✓	✓	17 years
P5	Senior Quantity Surveyor	BSc:(Hons) Quantity Surveying	✓	✓	✓	11 years
P6	Senior Quantity Surveyor	BSc:(Hons) Quantity Surveying	✓	✓	✓	13 years
P7	Senior Quantity Surveyor	BSc:(Hons) Quantity Surveying	✓	✓	✓	11 years

Where;

A1- Professional registration with the SACQSP

A2- Operates within the Eastern Cape province.

A3- Is a member of the ASAQs.

Incorporating circularity at the pre-contract stage

The thematic analysis revealed the themes of “Awareness of circularity” and “Integrating CE at the pre-contract stage”. These are discussed hereafter.

Theme 1: Understanding of Circularity

Table 2: Theme 1 categories and codes

Theme	Categories	Codes
Understanding of the Circular Economy	Economic Consideration	1. Entire Value Chain (P1, P6)
	Environmental Consideration	1. Reusing and Recycling (P2,P3,P7) 2. Reducing waste, reducing pollution (P5 , 3. Sustainability & Recycling (P7 ,
	Interconnectedness	1. Economy that fits together & Life cycle (P3 , P5, P6)

The participants noted that the concept of circularity was new to them. Nonetheless, when asked about their understanding of circularity, the participants responses were reflective of key tenets of circularity such as “reducing waste, recycling materials, sustainable practices and energy efficiency” as exemplified by participants 5 and participant 7 comments. *“Emm, I would say that basically an economy that sustains itself, I would, yeah! So, I can’t think of an example, but I would say definitely an economy that sustains itself, reduces waste, reduces pollution.”-P5.*

“Basically it has to do with sustainability and recycling. It’s about trying to use your materials in an effective manner... at times having to reuse and recycle them when the need arises, as opposed to constantly using new raw materials... umm within the industry.”-P7.

Notably, participants associated the concept with its three overarching principles of “reduce, reuse and recycle” (Ghisellini et al., 2016) and “going green and green buildings” as highlighted by participants 3 and participant 4 comments *“So, yeah, my understanding is that it’s the concept of trying to reuse or trying to use material or specify material”-P3.*

“Well, my understanding is that it’s, um...circular economy is making use of either recycling materials - recyclable or sustainable materials, recyclable materials... I mean as well as energy efficient building.”-P4.

However, when probed further about the application of circularity within the construction industry, a majority of the participants found it difficult or failed to appropriately explain its broader implications as highlighted by comments from P2, *“Uh... Look. It- It’s very difficult... uh. It’s quite a difficult topic to... almost track if I can call it that. Then um... normally. Like- Like - Okay, let me rather say it like this. We don’t have a- a knowledge as to how much of a product is actually recycled in, in the, in the if-if-if the architect or engineer spec something we won’t go and research whether or not this thing has been a recycled product”.* This difficulty may stem from a limited awareness among quantity surveyors regarding circular initiatives, which would align with Marsh et al., (2020) assertion, that the slow adoption of sustainable construction practices within the South African construction industry could be attributable to a low level of awareness regarding sustainability among built environment professionals.

Theme 2: Integrating CE at the pre-contract stage.

Table 3: Theme 2 categories and codes

Theme	Categories	Codes
Integrating CE at the Pre-Contract Stage	1. Decision-Making	1. Early Integration (P3,P6) 2. Critical Stage (P3,P5,P6) 3. Strategic Entry point (P4,P5,P6) 4. Perceived Challenges (P2,P4)
	2. Cost & Value Related	1. Cost planning & Estimating (P3) 2. Feasibility Studies (P5) 3. Value Engineering (P7) 4. Procurement Advice (P6,P7)

This theme explores the integration of CE in the construction industry. "Decision-making" and "Cost and Value-related" categories were revealed. These categories are discussed hereafter.

The pre-contract phase is pivotal for the successfully integration of sustainability within the construction industry (Gervásio, *et al.*, 2014). Furthermore, it is during this phase, where most critical project decisions are determined (Bragança *et al.*, 2014). *"So if you do not get it right to implement it there, you know it is going to be very difficult to implement it at any other stage of the project"-P3.*

"...pre-contract, because when you get to construction stage, every decision has already been taken, everything is finalised and now you just building according to what has been planned. Right? So it does have to be number 1 firstly; it has to be at the pre-contract stage because that's the only stage where you can effectively and make and take decision"-P5.

"Pre-contract stage is where I think most of your work needs to actually happen"-P6.

Basbagill *et al.*, (2013) asserts that decisions made at the pre-contract stage significantly impact a project's overall sustainability, making it imperative to integrate CE principles early in the project life cycle (Benachio *et al.*, 2020). A reduction in waste, pollution, and material consumption emerged as a key benefit of integrating CE at the pre-contract stage, where;

"The benefit would be reducing waste. Emm It would be reducing waste, It would be reducing pollution"-P5.

"... utilisation of recycled materials you get to decrease the utilisation of raw materials"-P7

Moreover, incorporating CE at the pre-contract stage makes it practical to incorporate circular value throughout a project's other lifecycle stages. Similarly, Wijewansha *et al.*, (2021) also observes that CE should be integrated at the pre-contract stage, where many project costs are assigned to ensure that circularity becomes seamlessly embedded into a project. Therefore, despite the pre-contract stage being perceived as complex and unsupportive of CE by two participants, it emerges as an essential and strategic entry point for the successful integration of circularity within the construction industry, underscoring the urgent need to raise awareness levels among BE professionals.

"It is very difficult. It is actually extremely difficult to do it at pre-tender stage..."-P2

"Pre-contract... Um... I don't know if it would benefit pre-contracts. The pre-contract stage wouldn't - I mean..."-P4

Participant 1 highlighted "reduce and reuse" as principles of CE that can easily be aligned with the quantity surveyors pre-contract roles, which partly resonates with Khan and Ali, (2022) findings that the "reduce" principle can easily be integrated within the context of a developing country that may otherwise be resource constrained.

"I think the reduce, reuse could be aligned because largely, the quantity surveyor is tasked with finances and budget of the project"-P1.

Most pre-contract QS roles identified within the literature were found to be supportive of the CE, with "cost planning and estimating" highlighted as the most crucial for integrating CE (Victar *et al.*, 2022), owing to the quantity surveyors' influence on cost (Morrison *et al.*, 2022).

"At pre-contract. I mean, that is basically when you when you do all the planning, estimating you know...So if you don't get it right to implement it there you know it's going to be very difficult to implement it at any other stage of the of the project"-P3.

"Cost estimating and planning" was also highlighted by four other participants as being supportive of CE, further emphasising the importance of the role in the success of a project. Cost estimating and planning guide the client on the anticipated project expenses and the likely time the expenses will be incurred (Chamikara *et al.*, 2020).

Four other QS pre-contract roles were highlighted as being supportive of CE; "Advice on procurement route," "Feasibility studies," "Tender documentation specification," and "Value engineering."

"...we are able to then advise on some of the procurement processes as well."-P7.

"...sorry feasibility studies, because that comes right at the beginning before you even get to a detailed design, right? where you can then propose certain methods that you are familiar with as the quantity surveyor for implementing the circular economy..."P5

"So possibly a way of integrating circular economy at that stage and our additional skills would be possibly in your tender documentation..."-P6

"...we normally conduct value engineering during this phase and... it presents opportunity for us to then suggest or advise on alternative materials which could possibly be cheaper, but without compromising on the efficiency of the particular building that the client umm... the product we want to deliver to the client so..."-P7.

Similarly, Victor *et al.* (2022) find "cost control, cost planning, feasibility studies, sustainability advisor, risk management and value engineering" pre-contract roles that could support CE at the design stage. Chamikara *et al.*, (2020) highlight "procurement advice," "value management," and "sustainability advisor" as essential roles for the achievement of CBE. Chamikara *et al.* (2020) accentuate procurement advice as having an integral role in influencing profitability, minimising unnecessary expenses, mitigating project delays, and accelerating the procurement process. These findings are consistent with prior studies (Victor, 2022; Chamikara, *et al.*, 2022) that underscore the compatibility of QS pre-contract roles in facilitating the integration of CE principles within the construction industry.

Conclusion

The pre-contract stage has emerged as a critical entry point for the successful integration of CE within the construction industry, to effectively address the prevailing environmental concerns within the sector, through a reduction in waste, pollution, and material consumption. Accordingly, quantity surveyors can help foster CE by strategically aligning their pre-contract roles with the tenets of circularity. Despite the need for enhanced awareness being a significant theme, decision-making, and cost and value-related roles emerged as pivotal roles that can be used to promote circular value throughout a project's lifecycle. Furthermore, the integration of CE principles within the construction industry not only brings about significant benefits, but also helps align it with several SDG's, underscoring the concepts strategic importance in driving transformational change within South Africa's construction industry. Therefore, there is an urgent need to raise awareness amongst quantity surveyors as well as other BE professionals regarding the potential benefit of CE in mitigating the prevailing environmental challenges within the sector.

Recommendations

To address the prevailing misconceptions and raise the levels of awareness among quantity surveyors, the association of South African Quantity Surveyors (ASAQS) could consider introducing continuous development programmes (CPD) geared towards sensitising quantity surveyors about the environmental and economic benefits of incorporating CE initiatives within the built environment. Additionally, the ASAQS could also consider further collaborative efforts with other BE professional bodies, sustainability organisations and relevant government departments to develop a more holistic approach towards the integration of CE in the construction sector.

Institutions of higher education could consider introducing and/or enhancing their quantity surveying programmes to align their existing curricula with aspects of circularity to equip students with the necessary skills prior to their entry in the job market. Similarly, these institutions could also consider

offering short course programmes geared towards the circular built environment to capacitate already practicing quantity surveyors with the necessary skills to drive CE in the construction industry.

Existing public and private procurement policies within the construction industry could also be restructured to include requirements for CE compliance in both design and project execution as a strategy to expedite the integration of CE within the sector.

Limitations

A limited availability of similar literature especially within a South African context constrained the depth and scope of literature available for this study. To address this limitation, additional literature was sought from international sources.

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Digital Transformation Drivers in Quantity Surveying: Objectives, Enablers and Leadership

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Abstract

The purpose of this paper is to explore the digital transformation (DX) journey within quantity surveying firms, focusing on the objectives driving these initiatives, the technological enablers facilitating the transformation, and the crucial role of leadership in ensuring successful implementation. As the construction industry undergoes rapid digitalisation, quantity surveying firms must adapt to maintain competitiveness and relevance in a changing market. This research employs a qualitative methodology, utilising semi-structured interviews with eight quantity surveyors actively engaged in digital transformation within their firms. Thematic analysis was used to identify key themes related to the objectives, enablers, and leadership roles in DX. The study's scope primarily focuses on the South African context, considering the unique challenges and opportunities faced by firms in this region. The findings reveal that while digital transformation is generally understood as the shift from manual to digital processes, practitioners have no universally agreed-upon definition. The study highlights the importance of aligning with global trends, improving operational efficiency, and enhancing collaboration as primary objectives of DX. Technological enablers such as Building Information Modelling (BIM), cloud computing, and advanced project management software are identified as critical to this process. Furthermore, the research underscores the pivotal role of leadership in guiding firms through digital transformation, with effective leaders championing digital initiatives and fostering a culture of innovation. The practical implications are significant. The findings presented here are designed to offer practical insights for industry professionals and academic researchers alike, providing a roadmap for future digital transformation efforts. The originality of this paper lies in its comprehensive examination of the interplay between digital transformation objectives, technological enablers, and leadership within quantity surveying firms. It provides valuable insights for industry professionals and academic researchers focused on digitalisation in the construction industry..

Keywords: Digital Transformation, Quantity Surveying, Leadership, Technological Enablers, Construction Industry.

Introduction

In the rapidly evolving construction industry landscape, digital transformation has emerged as a pivotal force shaping the future of quantity surveying. As technological advancements accelerate, quantity surveying firms must embrace digital tools and practices to maintain their competitive edge and relevance. The construction sector, historically slow to adopt technological innovations, now finds itself at a critical juncture where failure to integrate digital transformation could result in obsolescence (Custers, 2023; Akinshipe, Ikuabe & Aigbavboa, 2022). This paper explores the digital revolution within the quantity surveying profession, emphasising the objectives, technological enablers, and leadership dynamics that drive successful digital transformation.

Digital transformation is not merely a trend but a fundamental shift in how businesses operate and compete in the modern economy (Vial, 2019). Traditionally grounded in meticulous cost management and contractual expertise, quantity surveying must now navigate the complexities of integrating digital technologies into its core practices. This research was conducted in South Africa, where quantity

surveying firms face unique challenges and opportunities in their digital transformation journey. The scope of this study spans key metropolitan areas, including Johannesburg, Cape Town, and Durban, where leading firms are at the forefront of embracing digital change (Agyekum, Ayarkwa & Acheampong, 2015).

This research seeks to fill a critical gap in the existing literature on digital transformation in quantity surveying. While previous studies have acknowledged the potential benefits of digitalisation in the construction industry (Akinshipe, Aigbavboa, Oke & Sekati, 2021), they often fail to address the specific challenges faced by quantity surveying firms. Moreover, there is a paucity of research examining the role of leadership in guiding digital transformation efforts within this field (Oberer & Erkollar, 2018). This paper aims to bridge these gaps by providing a comprehensive analysis of how digital transformation objectives are established, the technological enablers that facilitate this shift, and the crucial role of leadership in driving these changes (Ismail, Khater & Zaki, 2017).

Despite the growing body of research on digital transformation, there remains a significant void in understanding the practical application of these concepts within the quantity surveying profession (Dilmegani, 2019). This study challenges the existing literature by questioning the assumption that digital transformation is uniformly applicable across all construction industry sectors. Instead, it argues that the success of digital transformation in quantity surveying is contingent upon a nuanced understanding of the profession's unique needs and the strategic implementation of tailored technological solutions (Shen, Li, Shen, Drew & Chung, 2003). The cost of neglecting this transformation could be severe, leading to diminished competitiveness and eventual market exit for firms that fail to adapt (Chikochi, 2021).

The purpose of this research is to provide a focused investigation into the following key areas:

- To examine the objectives of digital transformation within quantity surveying firms.
- To identify the technological enablers critical for successful digital transformation.
- To evaluate the role of leadership in facilitating digital transformation.

These objectives are intended to guide quantity surveying firms in navigating their digital transformation journeys, ensuring they remain competitive and relevant in an increasingly digitalised construction industry.

The central argument of this paper is that successful digital transformation in quantity surveying is not merely a technological upgrade but a strategic shift that requires visionary leadership, clear objectives, and the careful selection of technological tools. This paper explored the key objectives driving digital transformation within quantity surveying firms, with the discussion grounded in the context of the evolving landscape of the construction industry. The research further conducted a detailed analysis of the technological enablers that support these transformations, emphasising the tools and innovations that facilitate digitalisation in quantity surveying practices.

The outlined research methodology, focused on the qualitative approach used to gather insights from industry professionals. The findings presented concerning the identified objectives and technological enablers, followed by a discussion on the critical role of leadership in steering digital transformation efforts. Finally, the paper concluded with practical recommendations for quantity surveying firms, underscoring the importance of strategic leadership and continuous adaptation to successfully navigate the digital revolution.

Literature Review

Introduction to digital transformation

Digital transformation has become essential across various industries, including quantity surveying, which plays a significant role in maintaining competitiveness. Vial (2019) suggests that digital transformation is more than just a technological upgrade; it represents a fundamental shift in how businesses operate and interact with their environments. This shift is particularly important in the construction industry, where traditional practices are increasingly being augmented or replaced by digital technologies. According to Akinshipe, Ikuabe, and Aigbavboa (2022), the construction industry has been notably slow in adopting these technological advancements, placing firms at risk of falling

behind in the competitive landscape. The adoption of digital tools enables quantity surveying firms to enhance operational efficiency and adapt to the rapidly changing demands of the market. This transformation allows firms to streamline their processes and provide more accurate and timely client services, thereby gaining a competitive edge. As Adegbembo and Moyanga (2020) note, the ongoing integration of technological innovations is crucial for the long-term survival of quantity surveying firms, particularly in an environment marked by severe rivalry and complex challenges. Integrating digital technologies in quantity surveying is not merely about improving current practices but about reshaping the profession's future. As the industry continues to evolve, it is crucial to understand the specific objectives that drive digital transformation within quantity surveying firms.

Objectives of digital transformation

In order to understand the desired objectives, organisations looking to begin a successful transformation journey must understand why they want to transform, which facets of the firm seek transformation, technologies to take advantage of, and the desired outputs of these transformations (Morakanyane, O'Reilly, McAvoy & Grace, 2020:4). According to Ibem and Laryea (2014:14) the construction industry adopts digital innovations slower, as compared to other industries. It has been observed that the most significant digital transformation occurs in the manufacturing (Dall'Omo, 2017:1), banking (Mladenovic, 2018), and telecommunication sectors of most developed countries (Agyekum et al., 2015:49). The consequence of such conditions is that less developed countries are experiencing a slow rate of digital transformation (Aghimien, Aigbavboa, Oke, Thwala & Moripe, 2022:1952).

Findings available from researchers (Ezeokoli et al., 2016:26), (Agenda, 2016), have highlighted several key drivers of digital transformation. These include increased profits and new revenue growth, improved effectiveness of operations, increased customer satisfactions, enhanced product innovation and greater flexibility. Moreover, they have found that DX often aims to achieve customer-centric processes, along with several other objectives, such as ensuring digital readiness, adapting to the changing competitive landscape, developing new business models and further enhancing customer satisfaction and engagement (van Tonder, Schachtebeck, Nieuwenhuizen & Bossink, 2020:112). As seen from this literature, the accumulated advantages of digital transformation serve as the main catalyst, shaping the development of DT objectives within organisations.

The objectives behind digital transformation in quantity surveying firms are multifaceted, aiming to enhance competitiveness and operational efficiency. Akinshipe et al. (2021) identify several key digital transformation objectives, including improving service delivery, increasing operational efficiency, and ensuring long-term competitiveness. These objectives are crucial for quantity surveying firms, which must continuously adapt to the evolving technological landscape to remain relevant in the industry. Firms can better position themselves in a competitive market by focusing on these objectives. For instance, improving service delivery through digital tools allows for more accurate cost estimation and project management, both critical aspects of quantity surveying. Furthermore, increasing operational efficiency through automation and digital workflows can reduce errors and save time, ultimately leading to cost savings and better project outcomes. The significance of these objectives is further highlighted by McKinsey and Company (2022), who found that the success rate of digital transformation efforts is relatively low, with only about 30% of large-scale transformations achieving their goals. This underscores the importance of a clear, well-defined set of objectives for guiding digital transformation initiatives. Exploring the technological enablers that facilitate digital transformation in quantity surveying firms is essential to achieving these objectives.

Technological enablers of digital transformation

The successful implementation of digital transformation in quantity surveying largely depends on adopting specific technological enablers. According to Agyekum, Ayarkwa, and Acheampong (2015), Building Information Modeling (BIM), cloud computing, and advanced project management software have transformed quantity surveying practices. These technologies enable firms to handle large datasets, collaborate in real-time with project stakeholders, and improve the accuracy of cost estimates. Adopting these technological enablers is critical for firms looking to stay ahead in the competitive landscape. BIM, for example, allows quantity surveyors to visualise project costs concerning the physical structure, leading to more informed decision-making. Cloud computing facilitates better data management and accessibility, while advanced project management software streamlines workflows and improves team communication. Yap et al. (2023) also emphasise the importance of overcoming

barriers to digital adoption, such as high operational costs and a lack of training, often cited as significant challenges in implementing digital technologies in the construction industry. These technologies collectively enhance the efficiency and effectiveness of quantity surveying services. While technology is a key driver of digital transformation, the role of leadership in guiding these efforts is equally important.

Digital transformation in quantity surveying firms requires specific enablers to ensure success. Krystallis *et al.* (2022) frame digital transformation as an innovation process, wherein businesses leverage emerging technologies to drive progress. Warner and Wäger (2019) describe digital transformation as the utilisation of innovative digital technologies to achieve business advancements. Over recent decades, three waves of digitalisation have transformed both businesses and societies: the introduction of computers to reduce paper usage and automate tasks, the global spread of the internet that reshaped value creation, and the development of new business models driven by technological advancements (van Tonder *et al.*, 2020).

Despite these challenges, IT tools are increasingly used in construction, especially in quantity surveying. Agyekum *et al.* (2015) list commonly used software such as WinQS, QS Plus2001, and Masterbill, while Akinshipe *et al.* (2021) recommend tools like CostX, Primus, and DimensionX for enhancing precision in tasks such as cost estimation and final accounts.

For successful digital transformation, quantity surveying firms must identify the right technologies that align with their strategic goals and adapt internal processes accordingly (Behrens *et al.*, 2023). Improving the integration of digital tools can optimise workflows by automating repetitive tasks, improving accuracy, and increasing overall efficiency while minimising human error (Yap *et al.*, 2023).

Leadership and digital transformation

Leadership plays a pivotal role in the successful digital transformation of quantity surveying firms, guiding the strategic direction and ensuring the workforce is prepared for change. Oberer and Erkollar (2018) emphasise the importance of visionary leadership in navigating digital transformation. They argue that leaders who are proactive in adopting and integrating digital technologies are more likely to achieve successful outcomes. Moreover, De la Boutetière, Montagner, and Reich (2018) found that organisations that successfully underwent digital transformation often did so with the involvement of new leaders knowledgeable and experienced in digital technologies. These leaders were instrumental in driving the change effort and ensuring the transformation aligned with the firm's strategic goals. Furthermore, Mhlungu, Chen, and Alkema (2019) argue that digital transformation requires a shift in organisational culture, moving away from traditional hierarchical structures towards more agile and collaborative ways of working. Effective leadership ensures that digital transformation is not just a top-down initiative but a holistic process involving all organisational levels. Leaders committed to digital transformation can inspire their teams to embrace new technologies and ways of working. Additionally, by providing the necessary training and resources, leaders can ensure that their teams are equipped to handle the challenges and opportunities that come with digital transformation. The interplay between technological enablers and leadership is crucial for the successful digital transformation of quantity surveying firms, as it determines the firm's ability to adapt and thrive in a rapidly changing environment.

This literature review established the foundation for understanding the critical aspects of digital transformation in quantity surveying, and focused on the objectives, technological enablers, and leadership required to drive this significant change.

Research Methodology and Method

This study employed a qualitative research methodology to explore the factors driving digital transformation within quantity surveying firms. The choice of a qualitative approach was made due to its ability to capture quantity surveyors' complex and nuanced experiences as they navigate the digital transformation process. This methodology allows for an in-depth understanding of the organisational, technological, and leadership factors influencing digital transformation, which would be challenging to quantify using quantitative methods.

Instrument

Semi-structured interviews were utilised as the primary data collection technique to gather detailed and context-rich data from participants. This method was chosen because it provides a structured framework while allowing flexibility to delve deeper into participants' responses. The interviews were conducted via online platforms such as MS Teams and Zoom, catering to participants' geographical distribution and availability. A total of eight interviews were conducted, each lasting between 30 and 45 minutes, which provided ample time for a thorough exploration of the themes related to digital transformation. These themes included technological enablers, leadership roles, and organisational preparedness. Data saturation was reached after these eight interviews, thereafter that no new significant themes emerged.

The interview guide was carefully developed to align with the research objectives, focusing on key themes such as the objectives of digital transformation, the strategies employed by firms, and the role of leadership in facilitating this transformation. The guide was formulated through a rigorous process, drawing on a comprehensive review of existing literature on digital transformation within the construction and quantity surveying sectors.

Population and sampling

The study focused on Quantity Surveyors who are actively involved in firms that have implemented digital transformation initiatives. This population was selected because of their direct experience with the processes and challenges associated with digital transformation in the quantity surveying field. Participants varied in terms of their roles, years of experience, and the specific technologies their firms had adopted.

A purposive sampling technique was employed to recruit participants for this study. This method was selected due to the specialised nature of the target population, where participants were chosen based on their knowledge and involvement in digital transformation within their firms. A select group of quantity surveyors was initially identified through professional networks and industry contacts. As the study progressed, a snowball sampling technique was used, where these initial participants referred other relevant professionals who met the study's criteria. This approach effectively reached individuals with the requisite experience and insights, ensuring a diverse and knowledgeable participant pool as can be seen in Table 1 below.

Table 1: Participant pool

Participant	Location	Education	Experience	Position/Title	Branches of Firms
A	Durban	BSc. Quantity Surveying Honours	29 years	Director	JHB, CPT, PTA, Mauritius, Victoria, Gaborone, Maputo, Nairobi, Lagos,
B	Cape Town	BSc. Construction Management	17 years	Digital Specialist	Middle East, China, Europe, India, New Zealand
C	Cape Town	BSc. Quantity Surveying Honours	6 years	Global Digital Arm Associate	JHB, DBN, PTA, Mauritius, Victoria, Gabarone, Maputo, Nairobi, Lagos
D	Pretoria	BEng Technology Management	18 years	Director/Shareholder	JHB, DBN, CPT, Mauritius, Victoria, Gabarone, Maputo, Nairobi, Lagos
E	Johannesburg	BSc. Quantity Surveying	16 years	Digital Lead for Africa	Asia, Europe, North & Latin America, Middle East, New Zealand,
F	Cape Town	BSc. Construction Management & Economics	25 years	Director	CPT, Mauritius, Botswana, Dubai, Saudi Arabia
G	Cape Town	BSc. Quantity Surveying	21 years	Owner	None
H	Cape Town	BSc. Quantity Surveying	27 years	Director/Shareholder	CPT, KZN

Data analysis

The data obtained from the interviews were analysed using thematic analysis, a method well-suited for identifying and interpreting patterns within qualitative data. The analysis followed the six-phase process established by Braun and Clarke (2006). First, the researcher familiarised themselves with the data by thoroughly reading the interview transcripts multiple times. This was followed by the generation of initial codes that captured significant data points related to digital transformation. These codes were then organised into potential themes, which were reviewed and refined to ensure they accurately represented the data. The final themes were analysed in relation to the research questions and existing literature, providing a robust and grounded understanding of the digital transformation processes within quantity surveying firms.

This structured methodology enabled a comprehensive exploration of the key factors influencing digital transformation, providing valuable insights into the roles of technology, leadership, and organisational strategy in shaping the future of quantity surveying.

Research Results and Discussion

The thematic analysis of the data collected from eight semi-structured interviews yielded key themes that align with the research objectives. Each theme was established through a systematic coding process, supported by direct quotes from participants, and related to the literature reviewed. The themes explore the objectives of digital transformation within quantity surveying firms, the technological enablers for successful digital transformation, and the role of leadership in this process.

The themes are organised according to the following objectives:

- **Examine the Objectives of Digital Transformation within Quantity Surveying Firms:** This objective is addressed through the themes “Digital Transformation Defined,” which explores how firms define DX, “Opportunities that Prompted the Firm to Embark on a DX Journey,” which investigates the factors driving firms to pursue digital transformation, and “Goals Translated into Competitive Edges of DX,” which examines how these objectives enhance the competitiveness of firms.
- **Identify the Technological Enablers for Successful Digital Transformation:** This objective is explored through the themes “Technological Enablers Advancing Quantity Surveying Practices,” which identifies the tools and technologies that facilitate digital transformation, and “Barriers to Adopting Innovative Technology,” which discusses the challenges firms face in adopting new technologies.
- **Examine the Role of Leadership in Digital Transformation:** This objective is addressed through the themes “The Role of Leadership,” which highlights the influence of leadership on digital transformation, “The Change Champion,” which discusses the roles of individuals or committees dedicated to driving digital transformation, and “Adjustments to Leadership Styles,” which explores how leaders adapt their styles to support digital transformation.

Examine the objectives of digital transformation within quantity surveying firms

The theme “Digital Transformation Defined” was developed by identifying codes from the interviews that reflected how quantity surveying firms define digital transformation (DX) for themselves. The coding tree started with broad categories such as “understanding of DX” and “technology-enabled change,” which were refined into the theme. Participants’ definitions varied, with some emphasising the shift from manual methods to digital processes, while others focused on DX as a change in mindset or operational framework. Participant H described DX as “an evolution in tools... we commenced our careers with cut and shuffle paper, scale rulers, colouring pencils etc., and now things are done on computers and servers.” Participant A echoed this sentiment: “We used to do everything manually, producing everything with a method called cut and shuffle.” Meanwhile, Participant C offered a different perspective, viewing DX as “changing the mindset... embracing a new way of thinking that recognises the transformative potential of digital technologies.” The lack of a universally agreed-upon definition of digital transformation among participants mirrors the broader academic debate on the concept. As noted in the literature, digital transformation is often defined in terms of its outcomes, such as increased efficiency or competitive advantage, rather than a single, clear-cut definition (Demlehner & Laumer, 2019; Legner *et al.*, 2017). The findings align with Ismail, Khater, and Zaki (2017), who stress that organisations must continually evolve to remain competitive.

The theme “Opportunities that Prompted the Firm to Embark on a DX Journey” emerged from codes that captured the reasons why firms decided to embark on a digital transformation journey. The coding tree included categories such as “global alignment,” “competitive pressures,” and “response to COVID-19”. Participants highlighted the need to align with international counterparts and remain competitive in a rapidly changing industry as primary motivators. Participant A stated, “Our international counterparts are continuously driving digital transformation, and changing the way we work.” Participant D added, “To do a lot of country-wide and worldwide work has been easier with having a centralised server, where we can bid even for an airport in Hong Kong.” Participant F pointed out the impact of competition, noting, “In order to stay competitive with our competitors... we need to maintain our systems equal, if not better, than the competitors out there.” The findings are consistent with the literature, which emphasises the role of competitive pressures and global trends in driving digital transformation (Akinshipe *et al.*, 2022). The COVID-19 pandemic, as highlighted by six participants, also accelerated digitalisation, a trend observed globally as firms adapted to remote work requirements.

The theme “Goals Translated into Competitive Edges of DX” was formulated by identifying the competitive advantages gained through digital transformation. The coding tree included categories such as “collaboration and communication,” “economic factors,” and “streamlined operations”. Participants emphasised how digital tools have enhanced their firms’ competitiveness by improving collaboration, reducing costs, and increasing operational efficiency. Participant D remarked, “We do production work in Mauritius... so you can basically sit anywhere in the world and work on it,” highlighting the benefits of digitalised collaboration. Participant B pointed to the economic advantages, stating, “We will then cut a lot of cost on each end as well, because we are able to do four weeks’ worth of work within four days.” Participant H summed up the operational benefits with, “Yes, efficiency!” reflecting the consensus on improved productivity. The results align with the literature that identifies the competitive advantages of digital transformation, such as increased profits, operational efficiency, and customer satisfaction (Dunne, 2014; Ezeokoli *et al.*, 2016). The participants’ emphasis on these benefits suggests that they view DX as a strategic tool for achieving and maintaining a competitive edge.

Identify the technological enablers for successful digital transformation

The theme “Technological Enablers Advancing Quantity Surveying Practices” was established from codes related to the tools and technologies that facilitate digital transformation. The coding tree included categories like “hardware,” “communication tools,” “data analysis tools,” and “software applications”. Participants discussed a range of technologies that have been instrumental in advancing their practices. Participant H noted the early stages of digital transformation, stating, “I think the leading edge of printers, dual screens, and computer monitors.” Participant C highlighted the use of Revit, saying, “The Revit model would be loaded onto our system and export the quantities without taking off any measures.” Participant E discussed specialised tools, stating, “You just literally go online, put in the details of your building... and then within seconds it gives you a report.” These findings are in line with the literature, which highlights the importance of technological enablers like CostX, DimX, and WinQS in modernising quantity surveying practices (Agyekum *et al.*, 2015). The adoption of these tools reflects the broader trend of digital transformation in the industry, as firms seek to enhance efficiency and competitiveness through technology.

The theme “Barriers to Adopting Innovative Technology” was developed by identifying the challenges hindering innovative technology adoption. The coding tree included categories such as “disruption,” “client willingness,” “lack of infrastructure,” “cybersecurity,” “knowledge barriers,” “financial cost,” and “employee resistance”. These barriers highlight the difficulties firms face in fully embracing digital transformation. Participant C mentioned the disruptive nature of new technology, stating, “It always takes time for people to get used to it... finding the time to train people on new software.” Participant E discussed client resistance, noting, “The client didn’t want people to know what they were doing, and believed the digital tool would give other people in the business visibility.” Participant G emphasised the financial aspect, stating, “It’s expensive. And I would say the biggest barrier is cost.” The results support the literature, which identifies barriers like high operational costs, lack of training, and resistance to change as significant challenges in digital transformation (Yap *et al.*, 2023). Addressing these barriers is crucial for firms to fully leverage the potential of digital technologies.

Examine the role of leadership in digital transformation

The theme “The Role of Leadership” was formed by identifying codes related to the influence of leadership on digital transformation. The coding tree included categories like “leadership influence,” “visionary leadership,” and “organisational culture.” Participants highlighted leaders’ critical role in steering digital transformation efforts and ensuring their success. Participant A stated, “All your staff members look up to the leaders and the directors as to where the company’s direction is going.” Participant H emphasised the importance of leadership, saying, “Leadership sustains the business going forward.” Participant E discussed the need for financial backing, noting, “Leaders need to ensure the financial backing of initiatives is available.” These findings align with the literature, which underscores the pivotal role of leadership in digital transformation. De la Boutetière et al. (2018) found that organisations with strong, visionary leadership are more likely to succeed in their digital transformation efforts. The participants’ emphasis on leadership reflects the critical importance of leaders in driving change and fostering a culture of innovation.

The theme “The Change Champion” emerged from codes related to individuals or committees’ roles in driving digital transformation within firms. The coding tree included categories like “digital transformation committees,” “specialised roles,” and “change agents.” Participants discussed the importance of having dedicated personnel or groups to oversee and implement digital transformation initiatives. Participant A mentioned, “We’ve got a global digital transformation committee.” Participant B highlighted the specialised roles, stating, “It is my primary focus within the company to drive automation.” Participant F added, “There is generally one person in each office who will be part of that committee and will be the change agent in that office.” The concept of change champions aligns with the literature, which suggests that having dedicated individuals or committees is essential for successful digital transformation (Gale & Aarons, 2018). These roles ensure that digital initiatives are consistently monitored, adapted, and implemented effectively across the organisation.

The theme “Adjustments to Leadership Styles” was developed from codes related to how leaders adapt their styles to support digital transformation. The coding tree included categories like “self-development,” “acceptance,” and “open-minded mindset.” Participants emphasised the need for leaders to continuously refine their skills, remain open to change, and foster an environment of innovation.

Conclusion

This study explored the digital transformation journey within quantity surveying firms, focusing on the key objectives, technological enablers, and the role of leadership in this process. The findings from the thematic analysis provide significant insights into how digital transformation is defined and implemented within these firms, the challenges faced, and the competitive advantages gained.

The research reveals that participants generally understand digital transformation as a shift from traditional manual methods to digital processes, although there is some variation in how DX is conceptualised. This lack of a universally agreed-upon definition reflects digital transformation’s complexity and evolving nature. Nevertheless, all participants agreed on its critical importance for maintaining competitiveness in the modern business environment. The primary objectives identified include improving operational efficiency, enhancing communication and collaboration, and maintaining a competitive edge in a rapidly changing industry.

The decision to embark on a digital transformation journey was largely driven by the need to align with global trends, remain competitive, and respond to external pressures such as the COVID-19 pandemic. The study confirms that digital transformation is seen as essential for firms to compete globally and stay relevant in the market. These findings align with existing literature, emphasising digitalisation’s role in sustaining competitiveness.

Several key technological enablers have been identified as advancing quantity surveying practices, including hardware, communication tools, data analysis software, and specialised applications. These tools have significantly improved the efficiency and effectiveness of quantity surveying tasks. However, the adoption of these technologies is not without its challenges. The primary barriers include the high cost of technology, resistance to change, and infrastructure limitations. Addressing these barriers is essential for firms to realise the full benefits of digital transformation.

Leadership plays a critical role in driving and sustaining digital transformation efforts. Effective leadership involves guiding the firm through the digitalisation process and adapting leadership styles to support continuous innovation and change. Leaders must champion digital initiatives, provide the necessary resources, and foster an environment that encourages innovation. The presence of dedicated committees or individuals tasked with overseeing digital transformation efforts further underscores the importance of strong leadership in achieving successful outcomes.

In summary, this study highlights the critical importance of digital transformation in maintaining competitiveness within the quantity surveying industry. The successful implementation of digital transformation requires a clear understanding of its objectives, adopting appropriate technological enablers, and strong leadership to navigate challenges and drive continuous innovation. These findings suggest that firms must prioritise digital transformation as a strategic imperative and address the barriers hindering its progress to remain competitive in an increasingly digital world.

Recommendations

Based on the conclusions drawn from this study, several recommendations can be made to guide quantity surveying firms in their digital transformation efforts. First, firms need to develop a clear and unified understanding of digital transformation within their organisations. The study revealed a lack of consensus on the definition of digital transformation, which suggests that firms may benefit from workshops or training sessions that align the understanding of DX across all levels of the organisation. This will ensure that all employees are on the same page and can contribute effectively to the firm's digital goals.

Secondly, firms should actively address the barriers to technology adoption identified in the study. High costs, resistance to change, and infrastructure limitations were significant obstacles to digital transformation. To mitigate these challenges, it is recommended that firms seek out cost-effective technological solutions, provide continuous training to ease the transition for employees, and invest in upgrading their infrastructure to support new technologies. Addressing these barriers will enable firms to fully leverage the benefits of digital transformation, as highlighted in the conclusions.

Leadership within firms must play a proactive role in driving digital transformation. As the study emphasises, strong leadership is critical in guiding the firm through digitalisation and fostering a culture of innovation. Leaders should be encouraged to champion digital initiatives, provide necessary resources, and create an environment that supports continuous learning and adaptation. This recommendation follows directly from the conclusion that effective leadership is essential for successful digital transformation.

Finally, it is recommended that firms establish dedicated digital transformation committees or appoint change champions within their organisations. These individuals or groups should monitor progress, address challenges, and ensure that the firm remains on track with its digital transformation objectives. This recommendation is based on the conclusion that having dedicated personnel to oversee digital initiatives is vital for their success.

By implementing these recommendations, quantity surveying firms can enhance their digital transformation efforts, overcome barriers, and maintain a competitive edge in the industry.

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Digital Transformation or Stagnation: Unveiling the Paradoxes of Progress Among South African Quantity Surveyors

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Abstract

This paper explores the factors influencing digital transformation (DX) in quantity surveying in South Africa using the Technology-Organisation-Environment (TOE) framework. Identifying and analysing these key factors can enhance digital responsiveness, thereby contributing to sector performance and global competitiveness. Adopting a post-positivist research philosophy, this study follows a deductive approach. Quantitative data were collected via web-based questionnaires from 100 professionally registered Quantity Surveyors practising in the South African private sector. Descriptive statistics and mean item scores (MISs) were utilised to analyse the data. The analysis indicates that only 31% of the responding firms have a DX strategy. Within the technology construct, relative advantages such as increased work productivity drive DX, while perceived challenges like security risks and financial constraints hinder progress. Organisationally, there is a recognised need to balance traditional and emerging quantity surveying and emerging digital services. Environmentally, firms aim to add value for clients and stay competitive despite lacking benchmarking against competitors. Uncertainties regarding government support and erratic power supply further complicate DX efforts. This study is limited to South Africa and may not reflect other regions' socio-economic or political conditions. The self-reported nature of the survey data also constrains the findings. The research provides actionable insights to address challenges in DX. Practical recommendations include formulating clear DX strategies, advocating for government support and incentives, and increasing awareness of market opportunities through digital innovations. These strategies can help quantity surveying firms bridge the gap between current practices and future digital integration. This paper contributes to the limited literature on DX in the South African quantity surveying sector by identifying specific TOE drivers and barriers. The research offers a nuanced understanding of how these factors affect the adoption and implementation of DX initiatives, thereby advancing both academic knowledge and industry practice.

Keywords: Digital transformation, Quantity Surveying, Technology Adoption, South Africa, Technology-Organisation-Environment Framework.

Introduction

John F. Kennedy's ascertain that "Change is the law of life, and those who look only to the past or the present are certain to miss the future" (Kennedy, 1963) underscores the inevitability of evolution in various spheres, including business. The COVID-19 pandemic necessitated a rapid transformation in business operations, compelling firms to adapt swiftly to unprecedented circumstances (Fraser, 2021). A global study conducted by McKinsey revealed that the pandemic accelerated the adoption of digital technologies by several years, with many of these changes expected to endure (McKinsey Global Survey, 2020:1). In this context of digital transformation (DX), businesses often embark on this journey out of necessity to survive digital disruption (Jones, 2019).

The concept of DX was first introduced by the consulting firm CapGemini and the Massachusetts Institute of Technology Centre for Digital Business in late 2011, defined as "the use of technology to improve performance or the reach of businesses radically" (Lester, 2017:1). Maheshwari (2019:1) expands this definition, explaining that DX involves leveraging new technologies to drive substantial improvements across all business segments, including capitalising on new business opportunities and

transforming existing operations. A digitally transformed organisation is one that can swiftly respond to changing customer demands and convert technology into business outcomes and value (Maheshwari, 2019:1).

The notion of DX, which is inherently multi-disciplinary, has recently gained considerable attention as a research topic. To clarify this concept, Ekman, Dahlin, and Keller (2021:1) differentiate between "digitisation" and "digitalisation." Digitisation pertains to digital technologies, whereas digitalisation encompasses the broader socio-technical processes of adopting and utilising these technologies in various contexts, affecting individuals, organisations and societies. The impacts of digitalisation include changes in organisational structures, professional activities and the development of new business models (Ekman et al., 2021:1). This paper aligns with the view of digitalisation in discussing the complex process of DX.

Although Industry 4.0, primarily targets industrial companies, the rate of digital disruption is escalating across nearly every sector, with the construction industry being one of the last to experience this shift (Jones, 2019). DX is anticipated to significantly affect the construction industry's processes and financial performance. Researchers concur that DX can address four major challenges in the construction industry: productivity, safety and training, labour shortages and collaboration (Jones, 2019; Pee, Pan, Wang & Wu, 2021). A 2018 survey commissioned by Microsoft and the Royal Institute of British Architects (RIBA) revealed that the global construction industry is divided regarding its current state of DX (Bain, 2018). Architecture and design practices must consider the trends, opportunities and challenges DX presents to remain future-ready by discussing and planning necessary adaptations (Bain, 2018).

While existing literature addresses DX within the construction industry and architectural practices, there is a paucity of research on DX in the quantity surveying industry. South African Quantity Surveyors must challenge established thinking and traditional processes to move beyond outdated practices and structures, reshaping their roles to meet modern clients' current needs. An immediate challenge for the quantity surveying profession globally is developing and implementing effective processes and tools that integrate with information and communication technology (ICT) and digital innovations currently disrupting the construction industry. Quantity Surveyors must therefore, continuously evolve to address their ever-changing future roles (Llale & Root, 2023:402).

This research aims to explore the factors influencing quantity surveying firms' journey towards DX. Various factors could facilitate or impede Quantity Surveyors' agility and adoption of emerging technologies. However, there is limited information on the key factors and their influence on Quantity Surveyors in South Africa. This study utilises the Technology-Organisation-Environment (TOE) framework to identify the most significant factors. Analysing these key factors can enhance digital responsiveness and contribute to sector performance and global competitiveness. The objective of this paper is to promote the awareness and adoption of technology to achieve efficiency, diversity and innovative leadership. This paper's results could even be utilised to inform the South African government and professional bodies about the challenges faced when adopting DX in the quantity surveying sector.

Literature Review

South African quantity surveying context

Research on DX within the context of quantity surveying in South Africa remains limited. Existing global literature reports that DX adoption in the construction industry and among built environment professionals is slower compared to other industries (Haupt & Naidoo, 2016; Akinshipe *et al.*, 2021). This could suggest that South African Quantity Surveyors, by inference, also experience delays in adopting innovative technologies. Haupt and Naidoo (2016) conducted a study in KwaZulu-Natal, revealing that Quantity Surveyors lag behind in technology adoption, possess only average knowledge and experience of digital technologies, and struggle to comment on the relationship between technology and quantity surveying. This lack of expertise is largely attributed to insufficient knowledge of available technologies. Such findings underline the need for further research to understand the reasons behind this slow adoption rate.

Another study conducted in Gauteng describes the uptake of digital tools among Quantity Surveyors as "still quite low" (Akinshipe, Aigbavboa, Oke, & Sekati, 2021). These findings depict Quantity Surveyors as DX laggards, but they do not provide a comprehensive explanation for this phenomenon. Reddy (2015) aimed to explore the evolving functionality of the quantity surveying profession, noting that the industry is constantly changing, with increasing demands and expectations on professionals. As the roles of Quantity Surveyors expand, there is pressure to offer a wider range of innovative services to add value and meet market competition. Quantity Surveyors, therefore, need to diversify their services to stay competitive in a dynamic business environment (Chandramohan, Perera, & Dewagoda, 2020; Reddy, 2015).

Evolving roles and skills of quantity surveyors

In the context of these evolving industry requirements, Quantity Surveyors can continue to play a pivotal role by fulfilling multi-disciplinary functions. The modern definition of a Quantity Surveyor includes roles such as auditor, facilitator, leader and manager, emphasising the need for an innovative and dynamic approach (Reddy, 2015). Further emphasising the evolving role of the modern Quantity Surveyor, researchers identified an evolved role - which includes functions such as valuations, contract administration, project management, facilities management and appraisals, and an emerging role - which includes the functions of life cycle costing, strategic management, risk management, quality management, value management, sustainability management and BIM management, with respective functions beyond the traditional quantity surveying role (Haupt & Naidoo, 2016:25; Llaie & Root, 2023:402).

In the current digital landscape, Quantity Surveyors require a broad set of skills and knowledge, reinforcing the notion that the profession must be viewed as a multi-disciplinary practice aimed at achieving the best economic outcomes for projects. This requirement necessitates a commitment to continuous development and learning (Reddy, 2015; Shayan, Kim, Ma, & Freda, 2019). Adopting digital technologies could aid Quantity Surveyors in meeting the demands of their evolving roles, yet they face significant barriers and challenges throughout the DX process.

Application of the Technology-Organisation-Environment (TOE) framework

To investigate the barriers to digital maturity and the extent of DX among Quantity Surveyors, the Technology-Organisation-Environment (TOE) framework is implemented in this paper. The TOE framework is an established framework used to predict a firm's intention to adopt ICT. First proposed by DePietro, Wiarda, and Fleischer (1990) in Tomatzky, Fleischer, and Chakrabarti (1990), the TOE framework has a broad application in extend research, across a host of technological, industrial, and national/cultural contexts. The TOE model applies to research covering various topics relating to technological innovation and a broad spectrum of IS applications, such as e-commerce and cloud computing (Chatterjee, Rana, Dwivedi & Baabdullah, 2021).

Multiple studies incorporate the TOE framework as a lens to interpret the adoption of technology (Awa Ukoha & Emecheta, 2016:01; Jere & Ngidi, 2020:01; Ullah, Qayyum, Thaheem, Al-Turjman & Sepasgozar, 2021). The TOE model has been utilised to research technology adoption in several industries, including manufacturing, healthcare, retail, wholesale, and financial services. Likewise, the TOE framework has been tested in both developed and developing countries (Aljumah, 2023:382; Awa *et al.*, 2016:01; Chatterjee *et al.*, 2021; Gustomo, Abdurrahman & Prasetyo, 2024; Jere & Ngidi, 2020:01; Kechik, Luqman, Li & Leman, 2023:165; Ullah *et al.*, 2021). From the numerous applications in previous research, the TOE framework was deemed highly suitable for this paper to explore DX in the context of South African Quantity Surveyors.

The TOE framework consists of three core constructs, namely: the firm's technological, organisational and environmental contexts. Each of these constructs influences technological innovation and adoption, offering flexibility and suitability for analysing DX (Van Belle & Van Dyk, 2019). Van Belle and Van Dyk (*ibid*) applied the TOE framework to study technology adoption in the South African retail industry, while Jere and Ngidi (2020) used it to analyse technology adoption by small enterprises in Pietermaritzburg. Despite these applications, the context remains limited to retail and small enterprises, with no tested TOE framework for DX within the South African quantity surveying profession.

Integrating TOE Factors in digital transformation

Existing literature often considers TOE factors in isolation (Jere & Ngidi, 2020:01; Van Belle & Van Dyk, 2019), neglecting the integration of these constructs in a comprehensive DX pathway. This paper proposes an alternative view, integrating TOE factors as progressive levels of DX along a firm's pathway to digital maturity, extending considerations beyond the firm-level to the external environment.

For instance, technology as a construct involves evaluating and adopting internal and external innovations with minimal initial impact on DX. In the organisational context, the construct's range expands to include the suitability of the technologies within the organisation, necessitating increased knowledge and decision-making capacity to progress along the DX pathway. Finally, the environmental construct encompasses external factors such as industry trends, competition, client needs and government support, further extending the complexity and impact of DX (see visual presentation in Figure 1).

When firms consider the compounded factors of both the technological and organisational constructs, they progress from "laggards" to "followers". However, the factors of all three of the TOE constructs should be integrated and addressed simultaneously to ensure firms move ahead of the curve as "innovative leaders" (KPMG International, 2019).

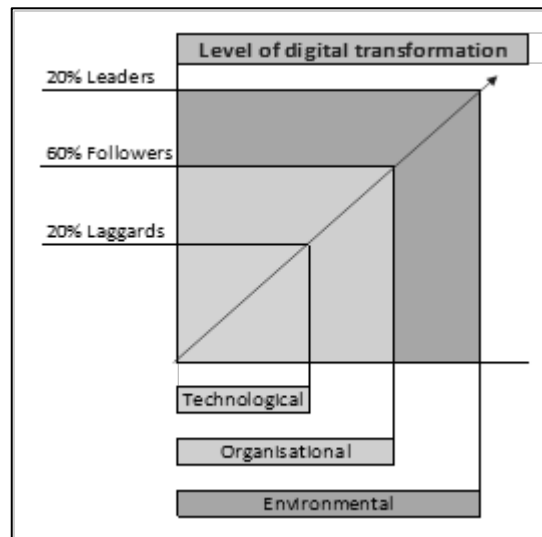


Figure 1: Level of DX within TOE framework (Source: Researcher's own proposal; percentages from KPMG International (2019))

The researcher selected four sub-constructs for each TOE construct in order to investigate the key factors influencing DX efforts among Quantity Surveyors. These sub-constructs are outlined in Table 1.

Table 1: TOE framework used in this paper (Source: Researcher's own choice)

Technology	Organisation	Environment
Compatibility	ICT knowledge & skills	Government
Complexity	Financial resources	Customer
Challenges	Company culture	Competition
Advantages	Top management	External support

Research Methodology and Method

With extensive DX and adoption theories available, this study follows a deductive approach to testing the TOE framework. Adopting a post-positivist research philosophy, this study collected quantitative data via web-based questionnaires from 100 professionally registered Quantity Surveyors practising in the South African private sector. This methodology was selected because quantitative methods allow measurement and analysis of relationships between variables through numerical data, facilitating a comprehensive understanding of the factors impacting DX. Mean item scores (MISs) were utilised to analyse and rank the data.

Sample size

To support this choice, it is essential to consider that quantitative research is particularly suited for studies aiming to generalise findings across a larger population. In this context, the study targeted 518 ASAQs-registered quantity surveying firms in South Africa. According to Krejcie and Morgan (1970), for a population size between 480 and 550, a sample of 217 is recommended to generalise findings. Leedy and Ormrod (2005) similarly suggest sampling 50% of the population at around 500.

Given the historically low response rates in construction-related questionnaires (Crafford & Smallwood, 2007), a census approach was deemed appropriate. This approach ensured a comprehensive data collection effort, achieving a 46% response rate, which exceeds the recommended 25% for construction industry research (Nkado, 2000) and further enables the researcher to generalise the study's findings.

Data collection

Data collection involved administering a web-based questionnaire, designed to gather primary data on the influence of TOE sub-constructs on DX. The questionnaire's development involved several stages to ensure its reliability and validity. Initially, the questionnaire was piloted with a small group of ten respondents to identify and correct any potential misperceptions or leading questions, such as the sub-construct of resistance to change. This piloting process included revising questions for clarity - for example, using the term manual methods rather than traditional methods, which is open to different interpretations. Thereafter, the instrument's reliability was re-tested.

The questionnaire consisted of four sections, with sections one to three measuring the influence of the TOE sub-constructs on DX. Respondents were asked to indicate their level of agreement with various statements using a five-point Likert scale. The fourth section collected demographic data to contextualise the study findings. This structured approach ensured that the data collected were comprehensive and relevant to the research objectives.

Data analysis and interpretation

For data analysis, descriptive statistics were utilised to establish the influence of the TOE sub-constructs. A mean item score (MIS) was calculated for the interval data, with ranges defined as follows: >1.00 to 1.80 (no influence/not important); >1.80 to <2.60 (little impact/slightly important); >2.60 to <3.40 (moderate influence/importance); >3.40 to <4.20 (somewhat influential/important); and >4.20 to 5.00 (very influential/important). The scores for respondents with and without a DX strategy were compared and the MISs allowed for a ranked order of the most to least influential sub-constructs, providing clear insights into the factors affecting DX.

Research Results

Of the completed questionnaires, 100 responses met the selection criteria. Among these respondents, only 31% indicated that their firm had a DX strategy. The low number further highlights the lack of DX efforts among South African firms when compared on an international scale (80% with a strategy) to the results from the 2019 Global Construction Survey (KPMG International, 2019).

Technological sub-constructs

The technological construct contained questions relating to each technological sub-construct: compatibility, complexity, perceived challenges and relative advantages. Responses are shown in Table 2. From these results, it is evident that respondents agreed that technology offers relative advantages.

Table 2: Ranked technological sub-constructs (Source: Researcher's own findings)

Construct	Sub-construct	MIS - overall	MIS - strategy	MIS - no strategy	Rank
Technological N = 100	Relative advantages	4.290	4.355	4.261	1
	Compatibility	4.014	4.194	3.932	2
	Complexity	3.948	4.036	3.908	3
	Perceived challenges	3.786	3.941	3.716	4

Among the *technological sub-constructs*, *relative advantages* associated with digital technologies and innovations were top ranked by respondents. Overall (4.290 MIS) respondents with a strategy (4.355 MIS) and those without a strategy (4.261 MIS) agreed that the biggest driver towards DX in the technological construct, was the relative advantages gained from digital technologies. The lowest ranked sub-construct was perceived challenges.

The individual statements relating to relative advantages were analysed (see Table 3), and respondents scored all three factors closely. Of all respondents, 80 - 88% either agreed or strongly agreed that DX or digital technologies could increase work productivity, aid accuracy and remove mundane elements of traditional quantity surveying.

Table 3: Relative advantages (Source: Researcher's own findings)

Sub-construct	Question	1 SD	2 D	3 N	4 A	5 SA	6 U	MIS - overall	Rank
Relative advantages N = 100	DX or digital technologies: Increase Quantity Surveyors' work productivity.	1%	1%	9%	28%	60%	1%	4.465	1
	Aid in the accuracy of quantity surveying work.	1%	2%	14%	31%	50%	2%	4.296	2
	Remove mundane elements of traditional quantity surveying.	2%	4%	14%	41%	39%	0%	4.110	3

Based on their MISs (between 4.2 and 5.0) the advantages of increased work productivity and accuracy were considered very important drivers influencing DX efforts. Similar results were found among small enterprises in Pietermaritzburg (Jere & Ngidi, 2020:01) and Malaysia (Chiu, Chen & Chen, 2017). The researchers found benefits gained by adopting digital technologies as one of the most important determinants influencing DX among enterprises. Of these benefits, increased productivity, improved communication and enhanced accuracy were identified in previous studies (Haupt & Naidoo, 2016:25; Akinshipe *et al.*, 2021: 255).

Individual statements relating to perceived challenges were examined (see Table 4), and it was found that the overall respondents (4.110 MIS) viewed DX as more beneficial than challenging. The major challenge identified was the security risks attributed to digital technologies.

Table 4: Perceived challenges (Source: Researcher's own findings)

Sub-construct	Question	1 SD	2 D	3 N	4 A	5 SA	6 U	MIS - overall	Rank
Perceived challenges N = 100	DX or digital technologies: Result in more benefits than challenges.	1%	5%	11%	48%	35%	0%	4.110	1
	Reduce the risk of data loss.	2%	11%	16%	34%	36%	1%	3.919	2
	Reduce security risks.	4%	17%	29%	32%	12%	6%	3.330	3

Although the benefits of adopting ICT identified in previous studies (Haupt & Naidoo, 2016:25; Akinshipe *et al.*, 2021: 255) include improved coordination and communication among stakeholders, the associated challenges also need to be considered. For effective digital collaboration, it is important to consider data security and protection. Data communications should be secure and access to collaborated information should be restricted to authorised stakeholders ((Oke, Aghimien, Aigbavboa & Koloko, 2018:2472).

From the results in Table 4, it is seen that 6% of the respondents are unsure about the security risks associated with DX. A further 21% of the respondents either disagree or strongly disagree that DX reduces security risks, making data security the biggest barrier to DX within the technological construct. This finding is not isolated among Quantity Surveyors, as another study (Van Belle & Van Dyk, 2019:519) identified security risks associated with DX as a perceived challenge among South African retailers. In the study, 83% of the interviewed retailers highlighted concerns about data protection.

Organisational sub-constructs

In the organisational construct, respondents were presented with questions relating to each of the sub-constructs: knowledge of ICT, financial resources, resistance to change (or traditional thinking), and top management support (or company culture). The responses indicated that Quantity Surveyors do not perceive resistance to change or traditional thinking as a barrier to DX. Table 5 indicates an overall MIS of 4.256, 4.496 among respondents with a DX strategy, and 4.147 among those without a strategy, meaning *resistance to change (or traditional thinking)* was the highest ranked *organisational sub-construct* and financial resources the lowest.

Table 5: Ranked organisational sub-constructs (Source: Researcher's own findings)

Construct	Sub-construct	MIS - overall	MIS - strategy	MIS - no strategy	Rank
Organisational N = 100	Resistance to change/ traditional thinking	4.256	4.496	4.147	1
	Top management/ company culture	3.746	4.140	3.562	2
	Knowledge of ICT	3.401	3.799	3.225	3
	Financial resources	2.959	3.183	2.858	4

From the individual statements (see Table 6), it is evident that 86% of the respondents either agreed or strongly agreed that DX does not remove the need for a Quantity Surveyor. Closely ranked in second place, respondents also agreed or strongly agreed (88%) that traditional quantity surveying services can co-exist with DX. Therefore, the surveyed Quantity Surveyors did not feel that DX will threaten their roles or profession. These findings align with a previous study (Haupt & Naidoo, 2016:25), where respondents tended to disagree or strongly disagree with statements that digital technologies would remove the demand for a Quantity Surveyor or present as a threat to services traditionally provided by Quantity Surveyors.

Another study (Akinshipe *et al.*, 2021: 255) found that South African Quantity Surveyors understand the effects of digitisation on the profession. From Table 6 it is clear that the respondents see DX positively influencing the profession. Instead of a barrier, the relationship between traditional quantity surveying services and digital innovation is seen as a top driver towards DX within the traditional thinking sub-construct.

Table 6: Resistance to change/traditional thinking (Source: Researcher's own findings)

Sub-construct	Question	1 SD	2 D	3 N	4 A	5 SA	6 U	MIS - overall	Rank
Resistance to change/traditional thinking N = 100	DX does not remove the need for a Quantity Surveyor.	2%	3%	5%	26%	60%	4%	4.448	1
	Traditional quantity surveying services will co-exist with DX.	1%	1%	7%	37%	51%	3%	4.402	2
	Our company culture encourages a balance between innovative technologies and tried-and-tested working methods.	1%	5%	20%	48%	25%	4%	3.919	3

With 57% of respondents either disagreeing or strongly disagreeing with the affordability of DX and another 2% indicating they are unsure, the financial resources sub-construct is seen as a major barrier to DX (shown in Table 7).

Table 7: Financial resources (Source: Researcher's own findings)

Sub-construct	Question	1 SD	2 D	3 N	4 A	5 SA	6 U	MIS - overall	Rank
Financial resources N = 100	DX is possible even with the additional training costs.	6%	13%	31%	43%	7%	0%	3.320	1
	The maintenance costs of technology are manageable.	4%	24%	29%	38%	5%	0%	3.160	2
	The upfront costs associated with DX are affordable.	22%	37%	18%	20%	1%	2%	2.398	3

It is important to note that financial resources within the organisational construct do not merely relate to the cost of digital technology, as this would be within the technological construct. As the organisational construct covers a bigger range in terms of DX (see Figure 1), the level of consideration of sub-constructs also increases. Therefore, at the organisational level, financial resources must include both the technology and the organisation. Financial resources would need to consider the costs of the technologies, training of staff (cost and time), and the maintenance costs involved for technological infrastructure (hardware), security and licences (software).

Environmental sub-constructs

With the bigger ambit of the organisational construct, a broader level of knowledge is required to meet the holistic level of DX. The survey responses in Table 8 show that the MISs for each sub-construct have reduced, due to an increase of "unsure" responses compared to the technological and organisational constructs. Respondents with and without DX strategies had slightly varying MISs in the technological and organisational constructs. Despite these small variances, all the respondents had a similar view regarding ranking the sub-constructs within these two contexts. In the environmental construct, DX's different levels (and knowledge) become more apparent, as the sub-construct influences are ranked differently (see **Table 8**) among the respondents with a DX strategy in place, compared to those without a strategy.

Table 8: Ranked environmental sub-constructs (Source: Researcher's own findings)

Construct	Sub-construct	MIS - overall	MIS - strategy	Rank	MIS - no strategy	Rank
Environmental N = 100	Competitive advantage/pressure	3.458	3.720	1	3.342	2
	Customer	3.318	3.397	2	3.283	3
	External support	3.310	3.195	3	3.362	1
	Government support	3.056	3.101	4	3.034	4

The overall MIS (3.458) indicates that respondents mostly agreed or strongly agreed that *competitive advantage or pressure in the external environment* had the biggest influence on DX. Respondents further ranked government support as the lowest driver towards DX. This sub-construct was also supported (3.72 MIS) among the respondents with a DX strategy. Respondents without a strategy, however, ranked external support as the most influential environmental sub-construct. All of the respondents ranked government support as the lowest DX driver, therefore, the sub-construct was analysed as a barrier.

Individual statements (Table 9) related to the competitive advantages digital technologies may offer and the pressure from digitally transforming competitors. Although the statement of adopting digital innovations to remain competitive was the highest ranked (by overall MIS), only 40% of respondents agreed and 27% strongly agreed (shown in Table 9). From the survey results it is important to note that the Quantity Surveyors have less knowledge of the environmental construct as they have not benchmarked their DX efforts against those of their competitors. This finding could be the reason for an increased percentage of "neutral" and "unsure" responses.

South African Quantity Surveyors may recognise technology and digital innovations' benefits (and competitive advantages). However, they lack DX knowledge (Haupt & Naidoo, 2016:25) compared to other South African industries. Within the retail industry, organisations must be informed across the TOE constructs, including their competitors in the external environment. Retailers must adapt, develop and transform to stay competitive as they monitor new technologies and what their competitors do in the market (Van Belle & Van Dyk, 2019:519).

Table 9: Competitive advantage/pressure (Source: Researcher's own findings)

Sub-construct	Question	1 SD	2 D	3 N	4 A	5 SA	6 U	MIS - overall	Rank
Competitive advantage/pressure N = 100	Our firm adopts new digital technologies to remain competitive.	4%	10%	17%	40%	27%	2%	3.776	1
	The adoption of digital technologies will lead to an increased market share.	2%	9%	23%	40%	17%	9%	3.670	2
	Our firm's competitors are lagging behind compared to our rate of DX.	8%	18%	37%	16%	6%	15%	2.929	3

With government support ranked as the lowest sub-construct (Table 8), individual factors were analysed for context and these scores are noted in Table 10.

Table 10: Government support (Source: Researcher's own findings)

Sub-construct	Question	1 SD	2 D	3 N	4 A	5 SA	6 U	MIS - overall	Rank
Government support N = 100	The erratic power supply in South Africa stifles DX.	4%	14%	11%	37%	30%	4%	3.781	1
	The lack of government policy confuses the legal ownership of digital information.	5%	18%	28%	17%	8%	24%	3.066	2
	Current legislation restricts the use of digital technologies.	21%	32%	25%	3%	6%	13%	2.322	3

With an overall MIS of 3.781 (from Table 10), the impediment of erratic power supply has a bigger, stifling impact on DX compared to the driver of adopting technologies to remain competitive (MIS of 3.776), as shown in Table 9. The barrier of the erratic or insufficient power supply may be somewhat important (MIS between 3.40 and 4.20). However, this is a common obstacle faced in developing countries like Jordan and Nigeria (Oke *et al.*, 2018:2472).

Discussion

This paper successfully identified the TOE factors that significantly impacted DX efforts among South African Quantity Surveyors. In the technological construct, relative advantages associated with digital technologies and innovations, such as increased work productivity and accuracy, had the biggest driving influence towards DX.

Among the organisational sub-constructs, resistance to change (or traditional thinking) was ranked as the highest driver towards DX. This finding indicates the accepting nature among respondents, who felt traditional quantity surveying services could co-exist with DX, instead of feeling threatened by DX.

Competitive advantage or pressure in the external environment had the biggest overall influence on DX among respondents, as adopting technology could lead to a competitive edge. In the external environment, a divide was noticed between respondents starting their DX efforts (with a DX strategy) and those who have not started their DX journey (without a DX strategy). The respondents with a DX strategy were driven towards DX as they considered the competitive advantages offered. Those without a DX strategy sought external support (such as vendor support) to drive their DX journey.

Government support regarding erratic power supply was found to be most influential barrier stifling DX efforts among respondents.

At face value, South African Quantity Surveyors at all levels of DX (with and without a strategy) tend to agree that digital technologies will positively impact on the industry. The majority agree that DX offers relative advantages at a technological level and competitive edges at an organisational level – yet South African Quantity Surveyors are not digitally advancing. They may agree with these advantages, but they do not realise these advantages in their own organisations, as a low 31% of respondents had a DX strategy in place.

Realistically, South African Quantity Surveyors are not confident in the co-existence of their traditional services and innovative technologies; they are complacent. Respondents lacked DX knowledge, particularly in the environmental construct, as the number of neutral and unsure responses increased.

If change is the law of life, the South African quantity surveying industry must adopt many changes to remain relevant. Quantity Surveyors can start their DX journey by formulating a clear DX strategy. Initial DX efforts could include comparing different digital technologies and assessing their benefits (technological level). Quantity Surveyors need to examine the costs associated with adopting digital technologies compared to the benefits gained.

In this regard, further research is recommended beyond the elementary level of quantity surveying software, such as BIM, CostX, and QSCAD. DX is a complex, on-going process that necessitates an evolving DX strategy. Quantity Surveyors cannot feel complacent by merely adopting a single digital technology. As Quantity Surveyors progress along their DX pathway, they need to benchmark their DX efforts against those of their competitors. Once Quantity Surveyors move towards digital maturity as

innovative leaders, they can be confident about their demand, as they are harnessing the DX benefits (i.e. productivity, accuracy, quality) when incorporating digital innovations to replace their mundane, traditional quantity surveying tasks.

Conclusion

From the research responses it can be concluded that South African Quantity Surveyors may recognise the benefits and competitive advantages gained from DX. However, this realisation is not enough to drive Quantity Surveyors towards DX. Compared to their international counterparts or other industries, South African Quantity Surveyors are stagnating in their DX efforts. Whilst the majority of Quantity Surveyors can be termed "laggards" or "behind the curve", their lack of DX knowledge, strategies, and benchmarking leave them in a vulnerable position. Without striving to reach their digital maturity, Quantity Surveyors have a false sense of complacency as they do not feel threatened by digital innovations.

Suppose Quantity Surveyors are faced with an increasing industry demand to evolve their role and functions. In that case, they need to harness the benefits of DX to meet these needs and stay relevant. South African Quantity Surveyors must advocate the benefits gained from digital innovations among the consultant team and the client, as these benefits will ultimately be shared with the client. If clients realise the benefits of DX, innovate technologies among the consultant team will be promoted and supported.

To further bridge the digital divide, the profession and the government must invest in education and training within the construction sector instead of driving labour-intensive projects to relieve unemployment. With focussed investment in education and training, quantity surveying graduates could enter the industry with enhanced digital knowledge, better equipping them for the evolving needs of the profession. Respondents identified government support, particularly erratic power supply, as one of the biggest challenges faced, which must be addressed to enable DX in the industry.

Recommendations

Quantity Surveyors need to formulate and implement a clear DX strategy which addresses the increasing scope of the TOE constructs. The organisation's DX objectives need to be driven from the top down to ensure a company culture that embraces DX whilst maintaining a competitive edge.

Additional insights could be gained from further research into client perceptions. If clients believe that digital innovations can replace the role of a Quantity Surveyor, it could be a vital finding. If client demand for digital technologies exists in the quantity surveying industry, the demand could drive increased digital knowledge and DX efforts. In turn, improved digital knowledge and DX efforts could ensure that the significance of a Quantity Surveyor's role is still realised in the digital age.

Further research is recommended among the few digital leaders who have reached digital maturity in the South African quantity surveying industry. These firms can be investigated through case studies to provide insights into their DX journey, the challenges faced and benefits gained. These insights can simplify the process for firms starting their DX efforts and provide an alternative view to this study's self-reported survey. International research provides insights into other regions' socio-economic or political conditions, and future research can further investigate the similarities and disparities between the contexts of these regions and South Africa.

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Effective Strategies for Advancing Sustainable Construction in South Africa: the Issue of Leadership

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Abstract

This research analyses the impact of leadership on the gradual implementation of sustainable construction (SC) methods in South Africa. The study first sought to gather and analyse data on the status of SC adoption in South Africa; nevertheless, a reoccurring theme of leadership surfaced during data analysis, necessitating a more thorough examination of its influence. As a result, this study examines the ambiguous leadership roles of key stakeholders—clients, contractors, and professional teams—and their impact on the slow adoption of SC innovations. A qualitative case study methodology was utilised, employing purposive sampling to select 34 industry professionals for semi-structured interviews across six construction projects in three South African cities. Thematic analysis indicated that although professional teams have the requisite technical expertise to spearhead SC initiatives, their efficacy is frequently compromised by clients' financial management and the operational difficulties encountered by contractors. The absence of government incentives and well-defined regulatory frameworks intensifies these delays. The findings highlight the necessity for a unified leadership framework that distinctly defines responsibilities and authority among all stakeholders to successfully tackle challenges to SC implementation. Future research should investigate the professional team's hesitance to embrace leadership, concentrating on whether training, incentives, or more robust governmental mandates could augment their participation in SC. Comparative investigations from different nations may yield insights into overcoming current barriers in SC adoption. By emphasising the essential role of robust, transparent and collaborative leadership, this research aims to contribute to a more integrated and successful adoption of sustainable practices in the construction industry.

Keywords: Innovation, Integrated Collaboration, Leadership, Sustainable Construction, Project Management.

Introduction

Sustainable construction (SC) encompasses ecologically responsible and resource-efficient methods throughout a building's life cycle, including design, construction, and deconstruction (Kumar, 2024; Warang et al., 2023). It emphasises the utilisation of sustainable materials and energy-efficient technology to minimise waste and environmental effect (Aghazadeh & Yildirim, 2021; Stanca, 2023). Global supply chain trends integrate advanced materials (Bublievsky & Lapyrev, 2023), innovative technology (Bhuiyan & Hammad, 2024), and strategic methodologies (Chen et al., 2017) to combat climate change and resource depletion. The construction industry, accountable for 40% of worldwide carbon emissions and 25% of solid waste (Kix, 2023), must use sustainable practices to alleviate these impacts. Nonetheless, challenges remain, especially in developing nations where inadequate knowledge, financial limitations, and fragile governmental structures impede SC adoption (Windapo & Umeokafor, 2023). Leadership is essential in surmounting these obstacles by offering vision and coordination (Afzal & Tumpa, 2024; Waqar et al., 2024; Latiffi & Zulkiffli, 2021). In the absence of robust leadership, initiatives to advance sustainability in South Africa may become disjointed and inadequate to achieve environmental objectives.

This study analyses the necessity for improved coordination among stakeholders—clients, professional teams, contractors, and government—to tackle SC issues in South Africa. It examines the role of leadership in facilitating collaboration and offers solutions for enhancing stakeholder alignment and advancing SC adoption. The structure of the paper is structured as follows: it commences with an

examination of the leadership challenges inherent in SC, subsequently transitioning to a review of pertinent literature concerning leadership frameworks and the adoption of SC practices. The methodology section delineates the qualitative case study approach and the process of data collection via semi-structured interviews. The findings and discussion centre on the significance of leadership in the adoption of SC practices, culminating in practical recommendations aimed at bridging leadership gaps and proposing avenues for future research.

Literature Review

Leadership frameworks in construction organisations

The lack of leadership in SC significantly impedes the collaborative frameworks essential for realising sustainability goals (Azal & Tumpa, 2024). The intricate nature of the construction industry demands the establishment of strong leadership frameworks to address challenges and foster innovation (Han et al., 2024). Different leadership styles, such as charismatic, instrumental, strategic, and interactive, play a crucial role in promoting ecological innovation and collaboration (Chammas & Hernandez, 2019; Costa et al., 2023). The efficacy of these methodologies is contingent upon leaders incorporating ecological insights into their initiatives, thereby fostering organisational innovation (Bossink, 2004). In the absence of committed leadership, the integration of stakeholders is adversely affected, resulting in fragmented initiatives among clients, contractors, and professionals, as well as a lack of alignment in sustainability objectives (Koolwijk et al., 2018; Opoku & Fortune, 2011). The management of stakeholders, particularly in relation to supplier relationships and the distribution of risk, is often inadequate, which consequently undermines the success of projects (Shabaz et al., 2018).

Contemporary leadership theories, including neo-charismatic leadership and Leader-Member Exchange (LMX), underscore the importance of relational dynamics in responding to the evolving demands of the construction industry (Winkler, 2009). Quality frameworks such as Total Quality Management (TQM) enhance the quality of products and services through the facilitation of effective team integration (Delgado-Hernandez & Aspinwall, 2008; Baiden, 2006). Leadership should transcend conventional management methodologies that prioritise technology, instead adopting a client-centred and socially responsive framework (Pries et al., 2004). Effective leadership plays a vital role in cultivating a strong safety culture, thereby improving safety awareness via training and behavioural modification (Misman et al., 2008). Leadership development programs play a crucial role in fostering decision-making skills that are imperative for tackling challenges related to resource allocation, time management, and safety (Nasaruddin, 2019; Skipper & Bell, 2008). The function of construction project managers (CPMs) is of paramount importance, as their leadership responsibilities fluctuate according to situational variables, thereby influencing both team efficacy and project results (Senaratne & Samaraweera, 2015). The absence of robust leadership within SC results in misconceptions regarding the costs associated with sustainability, as well as a notable deficiency in client demand for sustainable practices. Proactive leadership is essential for addressing these challenges and realising the complete potential of SC.

The current body of literature encompasses topics such as health and safety, project management, and TQM; however, it reveals a notable deficiency in research pertaining to leadership within the context of SC. While leadership theories such as charismatic and strategic leadership are well-documented, their relevance to sustainability objectives has yet to be thoroughly examined (Bossink, 2004; Kirkpatrick & Locke, 1996). Contemporary research examines the influence of leadership on safety culture (Misnan et al., 2008) and the efficiency of project delivery (Nasaruddin, 2019), while there is a notable lack of attention towards the advancement of sustainable practices. This gap highlights the necessity of comprehending the influence of leadership on SC, especially in terms of how collaborative and shared leadership can promote ecological innovation across the project lifecycle (Koolwijk et al., 2018; Opoku & Fortune, 2011). The construction industry is in pressing need of adopting environmentally sustainable practices; however, the absence of comprehensive leadership frameworks centred on sustainability highlights a significant domain for academic investigation. Furthermore, the leadership models under consideration exhibit restricted applicability within the South African context, where disjointed initiatives impede the successful implementation of SC strategies (Windapo & Umeokafor, 2023).

Gaps in leadership in SC

Despite the growing emphasis on sustainable construction (SC), significant leadership gaps hinder its integration into traditional construction practices. A major challenge is the absence of comprehensive operational frameworks that incorporate sustainability across all project stages. The Operational Context Space (OCS) model aims to link sustainability requirements to specific project entities and phases, allowing for better evaluation of responsibility and performance (Matar et al., 2008). However, its application remains limited. In regions like the United States, companies such as Turner Construction Co. have demonstrated leadership by exceeding sustainability goals, particularly in recycling and indoor air quality management (Riley et al., 2003). Many construction organizations tend to prioritize environmental sustainability, often neglecting social and economic aspects, which restricts a holistic approach to sustainable development (Opoku & Ahmed, 2013). Leaders must expand their focus beyond environmental considerations and embed sustainability into overall business strategies, overcoming challenges like perceived high costs and lack of client demand (Opoku & Fortune, 2011). Additionally, the transfer of sustainability knowledge from research to practice is insufficient, exacerbated by the construction industry's fragmented nature and resistance to adopting sustainable practices (Persson, 2009). In the UK, various policies exist, yet a lack of consensus on SC implementation leads to inconsistent project-level practices (Gunatilake, 2013). In developing countries like Nigeria, inadequate collaboration and training among construction professionals severely limit SC adoption (Davies & Davies, 2017). There is also a significant gap between the expected and actual performance of green buildings, often due to unverified design assumptions. This highlights the need for comprehensive performance measurement tools to ensure sustainability objectives are met (Mallory-Hill & Gorgolewski, 2018). Addressing these leadership deficiencies requires a multifaceted strategy that includes stronger commitments from industry leaders, the development of operational frameworks, and improved mechanisms for knowledge transfer.

Historical context of sustainable construction in South Africa

The South African construction industry has made significant advancements in building a strategy framework with the goal of promoting reconstruction, development, and expansion (Rwelamila, 2020; Dithebe, et al., 2022). SC in South Africa is a multifaceted endeavour that involves corporate social responsibility (CSR) and improving productivity (Wentzel, et al., 2022). However, as a developing country, the industry still struggles with issues related to SC practices such as lack of awareness, inadequate government support, and limited access to advanced technologies (Windapo & Umeokafor, 2023). Additionally, misconceptions about the costs associated with SC, lack of sufficient financial commitment from clients (Ayorinde, et al., 2021), contractors' hesitation to adopt innovative technologies (Cooper, et al., 2022), and inadequate design and planning processes exacerbate these challenges. These issues often lead to inefficiencies and increased costs, making SC unattainable for low-income individuals (Akinyede & Fapohunda, 2023).

Stakeholder roles in sustainable construction

The involvement of stakeholders in SC is complex, encompassing a range of individuals including architects, engineers, constructors, government bodies, and the community (Primožič & Kutnar, 2024). Every stakeholder has a vital part to play in advancing sustainable practices, overcoming obstacles, and guaranteeing the smooth execution of SC projects (Juffle, et al., 2024). The active participation of industry stakeholders is essential in closing the divide between theoretical concepts and actual execution, hence promoting inclusive and equitable utilisation of resources (Karaca, et al., 2024). As brought out by Viswalekshmi and Bendi (2024), stakeholders have a significant impact on waste reduction in construction projects by implementing different strategies and frameworks. Active participation is crucial to implement efficient waste management practices, foster sustainability, and guarantee the smooth execution of construction projects (ibid). A construction professional's decisions, attitudes, and understanding significantly impact the adoption and implementation of SC (Laridou, et al., 2022). To effectively promote SC, stakeholders must have a thorough understanding of the local context, actively participate in decision-making processes, and consider environmental and social realities (Tokbolat, et al., 2019).

Barriers to sustainable construction

Extant literature discusses the barriers to application of SC practices. These widespread, well documented challenges are becoming more prevalent. However, there is a lack of evidence regarding effective strategies to tackle them. There seems to be a tendency for a financial bias when it comes to embracing sustainable practices, as some may view the initial cost as high and the return on investment as not immediately apparent (Ayalp & Metinal, 2024). The absence of robust national and international legislative frameworks that integrate sustainability criteria makes implementing SC practices challenging (Alhammadi, et al., 2024). Organisational culture and stakeholder dynamics pose substantial obstacles to the adoption of sustainable practices by stakeholders due to a lack of demand and fear of shifting from conventional construction technologies (Ayalp & Metinal, 2024). In developing countries, logistical challenges such as transportation and establishing coordination of prefabricated components have been a deterrent in adoption of SC (Jayawardana, et al., 2024; Ali, et al., 2024). Recognising the importance of finding the right leadership to spearhead SC is essential to address the ongoing obstacles and bring about the much-needed change in South Africa's construction sector.

The literature on SC continually emphasises the significance of leadership in promoting SC practices. Although global research has shown the efficacy of collaborative leadership frameworks, a notable gap exists in the South African context concerning the impact of leadership, or its absence, on the application of SC practices. This paper examines how the lack of clearly defined leadership roles hinders the timely implementation of SC in South Africa. This study provides new insights on optimising leadership structures to enhance SC adoption in the country by examining the roles of clients, contractors, and professional teams.

Research Methodology and Method

This study employed a qualitative technique to investigate the impact of leadership, or the lack thereof, on the postponed implementation of sustainable construction (SC) practices in South Africa. Due to the intricate and context-dependent characteristics of leadership in construction, qualitative methodologies were optimal for investigating participants' experiences and perceptions (Schweber & Chow, 2023; Spearing et al., 2022). This methodology yielded detailed insights into the leadership dynamics that contribute to SC delays (Alankarage et al., 2024; Knoll, 2023), uncovering themes that encapsulate the sociotechnical intricacies of leadership roles in construction projects (Umeokafor, 2015).

The case study design facilitated a comprehensive examination of real-world phenomena, investigating stakeholder interactions in SC initiatives (Alankarage et al., 2024). The research concentrated on six building projects in Johannesburg, Pietermaritzburg, and Polokwane, aiming at professionals in leadership positions, such as architects, quantity surveyors, project managers, contractors, and client representatives. A purposive sample method was employed to select 34 participants depending on their proficiency in SC (Umeokafor, 2015).

Data was gathered via semi-structured interviews, facilitating flexibility in examining leadership in SC while ensuring consistency through an interview guide comprising 19 questions. The data processing procedure encompassed transcription, coding, thematic analysis, and synthesis (Kara, 2023). This five-step analysis offered an in-depth examination of the leadership problems in SC.

Table 1: The summary of 6 projects and its participants investigated in this study

Project Description	Interviewees	Sustainability Focus	Project Budget	Project Duration
Upgrades and additions of community Theatre	Group 1: 1 STK, 2 Pr. CPM, 1 Pr. Arch Group 2: 1CM, 1FM, 1S&I Sub	Optimise resource utilisation: Prioritise the efficient use of resources and highlight the advantages for the community	ZAR 37 million	18 months
Upgrades and additions of community Library	Group 1: 1 STK, 1 Pr. CPM, 1 Pr. QS Group 2: 1CM, 1S&I Sub	Establish a secure setting that is devoid of hazardous compounds: Employ sustainable construction methods in the development of public infrastructure.	ZAR 22 million	18 months
Construction of community Clinic	Group 1: 2 STK, 1 Pr. CPM, 1 Pr. Arch	Utilise sustainable and recyclable materials: Implement environmentally friendly	ZAR 65 million	18 months

Project Description	Interviewees	Sustainability Focus	Project Budget	Project Duration
	Group 2: 1CM, 1S&I Sub	techniques, even when faced with financial constraints		
Construction of residential apartments – Phase 1	Group 1: 1 Dev, 1 Pr. CPM, 2 Pr. Arch, 1 Pr. QS Group 2: 1CM	Utilise sustainable and recyclable resources: Implement sustainable construction methods in large-scale projects.	ZAR 250 million	24 months
Construction of RDP houses	Group 1: 1 STK, 1 Pr. CPM, 2 Pr. QS Group 2: 1CM	Optimise resource utilisation: Implement sustainable construction techniques in smaller projects.	ZAR 13 million	14 months
Construction of fifty residential blocks	Group 1: 1 Pr. CPM, 1 Pr. QS Group 2: 1S&I Sub, 1FM	Optimise resource utilisation: Tackle obstacles and attain accomplishments in the adoption of sustainable practices on a broader scope.	ZAR 145 million	18 months

34 study participants

Notes: STK – Stakeholder; Pr.CPM- Professional Construction Project Manager; Pr. Arch – Professional Architect; CM – Construction Manager; Pr.QS – Professional Quantity Surveyor; S&I Sub – Supply & Install Subcontractor; FM – Foreman

Justification for focus on leadership

This study primarily sought to investigate the adoption of sustainable construction (SC), emphasising technical, procedural, and stakeholder-related dimensions. During data collection and analysis, leadership emerged as a prominent theme, indicating its significance as a vital factor influencing SC adoption. In qualitative research, themes frequently arise organically from the data because of meticulous, iterative analysis. This methodology facilitates the emergence of patterns and insights organically, rather than imposing them through the researcher's influence. In this investigation, the emergence of leadership as a pivotal theme within sustainable construction practices was not initially anticipated; however, it became apparent through the inductive methodology employed. At the outset, the emphasis was placed on comprehending the technical and procedural dimensions of SC adoption. Nevertheless, as the data collection advanced, the analysis indicated that deficiencies in leadership emerged as a persistent obstacle. This corresponds with the principle that inductive analysis facilitates the emergence of themes from the data devoid of preconceived notions, whereas deductive methodologies may be employed to evaluate established theories in relation to the data, thereby fostering a more thorough comprehension (Moeed, et al., 2024). The persistent focus on leadership evident in the responses of participants suggests that this element was pivotal in the protracted adoption of SC practices.

The endeavour of recognising leadership as a thematic element simultaneously illustrates the complexities associated with addressing “missing data,” wherein core themes may not be readily apparent. In alignment with other qualitative studies, it is imperative for researchers to address these gaps and enhance their analysis by incorporating participant feedback and engaging with the relevant literature (Singh & Richards, 2003; Hong, 2015). The iterative process undertaken, which entailed the synthesis of data alongside the existing literature on SC, revealed leadership as a critical issue, even though it was not the primary focus of the inquiry.

Moreover, the intricate relationship between data collection, analysis, and the formulation of theory, as emphasised by Humble & Radina (2025), was instrumental in refining the study's emphasis as leadership surfaced as a prevailing theme. This transition was characterised not solely by data but also by the contextual relevance and the closeness of terms and concepts associated with leadership as evidenced in the interview responses, paralleling observations made in other disciplines (Romano & Horesh, 2014). Thus, although the original research design was focused on evaluating SC adoption through a technical lens, the emergence of leadership during the data analysis phase warranted a more extensive investigation of this theme. By permitting the data to inform the study's emphasis, this research elucidates the critical role of leadership dynamics in overcoming the barriers to SC adoption, thereby offering profound insights into the sociotechnical challenges inherent in this field (Docherty & McColl, 2003; Armstrong et al., 2015; Walker et al., 2002).

Research Results

The objective of this study was to explore methods for enhancing cooperation among professional teams, clients, contractors, and government to successfully overcome obstacles and promote sustainable construction practices in South Africa was undertaken through the semi-structured interviews conducted with 34 project participants. Two data groups were interviewed from 3 cities in South Africa: Johannesburg, Pietermaritzburg and Polokwane. The interview protocol consisted of both closed and open-ended interviews with members of the professional team (registered professionals), client representatives, main contractors and their subcontractors. All 34 of the participants were involved in passive and active design projects. A summary of the projects investigated in this study is presented in Table 1. Each group's perceptions of leadership deficiencies and their impact on SC implementation are discussed in detail.

Clients' perception of leadership in sustainable construction

Clients, serving as pivotal financial decision-makers within construction projects, significantly influence the implementation of SC practices. Nonetheless, the preponderance of client representatives interviewed recognised a deficiency in leadership, especially concerning their insufficient commitment to sustainability. A considerable number of participants indicated that clients frequently emphasise immediate financial benefits at the expense of long-term environmental objectives, thereby hindering SC progress. A representative from the client organisation articulated:

"While we understand the importance of sustainability, the financial pressures we face mean that cost-saving measures often take precedence. If there's no clear leadership pushing for sustainable practices, it's easy to default to what we know" – STK, upgrade and addition of community theatre

This observation underscores the propensity of clients to relinquish leadership responsibilities to professional teams or contractors, which results in an absence of clear direction and subsequent delays in the adoption of SC practices. The lack of robust client leadership has been identified as a considerable obstacle to the implementation of sustainability initiatives, given that clients possess the financial authority to shape the sustainability agenda yet frequently exhibit hesitance in assuming this responsibility.

Professional teams and the leadership vacuum

The professional teams, which include architects, quantity surveyors, and project managers, are typically regarded as the foremost authorities on SC practices. Nevertheless, the findings suggest that although professional teams possess the requisite expertise to spearhead SC initiatives, they frequently encounter challenges in exercising leadership because of client constraints and contractor limitations. An architect observed:

"We have the knowledge and skills to integrate sustainable practices, but without the client's full backing, our hands are tied. It's hard to lead when the financial power lies elsewhere" – Pr. Arch, Construction of community clinic

Several participants from the professional teams underscored the necessity for a more clearly delineated leadership role, one that would enable them to steer both clients and contractors in the adoption of SC practices. Nevertheless, they recognised that the absence of authority conferred upon them by clients constrained their capacity to execute decisive measures. Moreover, certain professional teams expressed concerns regarding the inadequacy of governmental policies and incentives aimed at promoting sustainable practices, thereby intensifying the existing leadership void.

Contractors' role and leadership challenges

The contractors, tasked with the on-site execution of SC initiatives, articulated their dissatisfaction regarding the existing leadership framework—or the apparent absence of such—within sustainability projects. Numerous contractors have indicated that although they frequently bear the responsibility of implementing sustainable practices, the lack of definitive guidance from both clients and professional teams complicates their ability to meet sustainability objectives. A construction manager articulated:

“We’re expected to implement sustainable construction, but without clear direction or coordination from the top, it’s a challenge. Often, we end up doing what is necessary to complete the project” – CM, Construction of residential apartments phase 1

“This project incorporates the combination of both tradition and sustainable design, reason being that we are still behind when it comes the use of sustainable materials” – Pr. CPM, Construction of RDP houses

Contractors identified operational difficulties, including the higher costs associated with sustainable materials and the absence of coordinated planning among stakeholders, which impeded their capacity to address SC concerns effectively. Although they recognised their responsibility in advancing SC on-site, contractors believed they were inadequately prepared to take the lead without stronger direction and assistance from clients and professional teams.

Discussion

The findings under the leadership theme revealed diverse perspectives on who ought to spearhead the promotion of SC practices in building projects. Participants articulated divergent opinions regarding whether the client, professional team, or contractors should bear this duty.

- i. Diverse Perspectives on Leadership - Clients were perceived by some as the inherent leaders, as they delineate the project scope, allocate finances, and determine the sustainability objectives. Their leadership is essential in establishing sustainability priorities from the project's outset.
- ii. Professional teams, such as architects, engineers, and quantity surveyors were recognised as prospective leaders owing to their technical proficiency. These professionals participate in the design process, during which critical decisions concerning sustainable procedures, materials, and technologies are determined.
- iii. Contractors were proposed as an alternative, as they oversee the daily execution of the project and are accountable for applying SC practices on-site. Their expertise in construction processes enables them to spearhead the implementation of sustainability.

The subsequent phase of analysis was directed at a thorough examination of the original data pertaining to the implementation of SC practices. This phase sought to evaluate which entity—be it the client, the professional team, or the contractor—ought to take the lead, contingent upon the technical requirements of SC projects. Through a thorough examination of the distinct roles and capacities of these entities in relation to the themes of SC, this analysis aimed to elucidate which group is most suitably positioned to lead the efforts in SC within the context of South Africa. This would assist in identifying the requisite leadership framework essential for promoting the integration of sustainable practices throughout the construction sector.

Table 2: Key Themes and Implications for Leadership in Sustainable Construction (SC)

SC Technical Themes	Key Insights	Implications for Leadership in SC
Theme 1 - The professional teams emphasised sustainability by promoting resource conservation and waste management to encourage community engagement:	Professional teams underscored the importance of sustainability by focussing on resource conservation and waste management, especially during the phases of project planning and design. Nevertheless, financial constraints frequently hindered the comprehensive execution of the initiative.	Professional teams are equipped with the requisite knowledge and skills to spearhead SC initiatives; however, they necessitate financial backing from their clients. The collaboration between professional teams and clients is of paramount importance for the effective exercise of leadership in SC.
Theme 2 - Striking a Balance Between Tradition and Sustainability in building	The construction teams endeavoured to integrate traditional methodologies with sustainable practices, with a particular emphasis on waste management. Nevertheless, the elevated expense associated with sustainable materials hinders comprehensive adoption. Contractors encountered various operational challenges; however, they were instrumental in devising effective on-site solutions.	Contractors play a vital role in the execution of sustainable practices on-site; however, they encounter various obstacles that hinder their ability to spearhead SC initiative. A harmonious integration of traditional practices with sustainability necessitates collaborative endeavours among all stakeholders involved.

SC Technical Themes	Key Insights	Implications for Leadership in SC
Theme 3 - Utilising the knowledge and skills of design teams is crucial for the sustainable development of projects	The contributions of design teams to sustainability are noteworthy, as they engage actively in the realms of planning, design, and cost management. Their influence was frequently constrained by the financial decisions made by clients.	The role of design teams is crucial in advancing sustainable practices; however, their effectiveness is contingent upon the collaboration of clients. A collaborative leadership strategy involving both design teams and clients is essential for achieving success in SC application.
Theme 5 - Promoting Social Responsibility and Equity in Construction	SC considerations encompass not only environmental factors but also social dimensions, which include community engagement and the well-being of workers. Contractors actively implemented these practices.	Social sustainability constitutes a shared obligation among all members of society. Contractors are integral to the implementation process; however, effective leadership in SC application necessitates collaborative efforts from all stakeholders, encompassing clients and professional teams alike.
Theme 6 - Obstacles in the field of sustainable development and SC practices	Systemic challenges such as poverty, regulatory deficiencies, and insufficient expertise impede the implementation of SC. Cooperative endeavours are essential to surmount these obstacles.	Effective SC leadership cannot be relegated to a single group; it necessitates collaboration among all stakeholders to overcome regulatory deficiencies and improve SC proficiency.
Theme 7 - Approaches for Attaining Sustainability in the Project	Strategies such as sustainable procurement and mentorship are essential for SC implementation and should be implemented from the initial planning stage. Professional teams are well-positioned to spearhead these initiatives, with client backing.	Professional teams, backed by clients, are well positioned to spearhead SC projects. The efficacy of these initiatives relies on the collaboration and dedication of all stakeholders involved.

Table 2 delineates the distinct roles and responsibilities of clients, professional teams, and contractors in advancing SC. It emphasises the necessity of collaborative leadership, since no singular entity can proficiently govern SC processes independently. Professional teams play a pivotal role in implementing sustainable practices; nevertheless, financial and regulatory backing from clients and the government is essential for their success.

Conclusion

The South African construction industry has advanced in SC, although faces obstacles such as inadequate awareness, insufficient governmental backing, and financial fallacies. The professional team, comprising designers, planners, and quantity surveyors, is ideally situated to spearhead SC initiatives; yet accountability is frequently perceived as the client's obligation. In the absence of a professional team actively advocating for and executing SC strategies, the industry may have difficulties in attaining sustainability objectives. The professional team, proficient in sustainable design and financial valuations, frequently delegates SC obligation to the client. This prompts the inquiry: if clients fail to adopt SC, should the professional team also be held accountable for not fostering innovation? For SC to thrive, the professional team must assume leadership, as their experience is essential for promoting sustainability within the industry.

Recommendations

To tackle leadership challenges and expedite SC adoption in South Africa, the subsequent measures are advised: Develop a definitive leadership framework delineating the responsibilities of clients, professional teams, and contractors. Professional teams, possessing technical expertise, must lead SC initiatives, while clients depend on their advice and guidance. Government support is essential via SC legislation and financial incentives, while client engagement can be fostered through training and rewards. Collaborative decision-making among all stakeholders is crucial for cohesive efforts. Subsequent research should investigate the professional team's reluctance to assume leadership, concentrating on whether training, incentives, or more robust governmental mandates could augment

their involvement in SC. Comparative analyses from other nations may offer suggestions for addressing existing issues in SC adoption.

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Effectiveness of the Risk Management Strategies Utilised by Quantity Surveyors in Namibia

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Abstract

The paper aims to evaluate the effectiveness of the risk management strategies utilised by quantity surveyors within contract administration in Namibia. It highlights the impact of poorly managed uncertainties on project outcomes. It intends to expose risk management strategies that significantly influence performance expectations of construction projects in Namibia from the perspective of client quantity surveyors. A positivist philosophy was instituted, and a questionnaire survey was deployed to all registered quantity surveyors firms in Namibia. The Pearson correlation coefficient was used to measure the relationship and comment on the effectiveness of the strategies implemented to address the significant performance risks. The results revealed five significant relationships, with progress and technical meetings having the most significant positive impact on client satisfaction. The second most important relationship was between the provision of quality control in contract administration and safety obligations on construction sites. Most of the risk management strategies showed insignificant efficacy. The study's major limitation was a low response rate (34%). The findings identified that risk management strategies with insignificant efficacy need to be addressed by improving their implementation or identifying alternatives. A higher performance in project delivery would be ensured by improving risk management strategies like extension of time (EOT), which quantity surveyors in Namibian construction projects use. The study determines the efficacy of risk management strategies and presents risk evaluation as a continuous improvement process in contract administration.

Keywords: Risk Management Strategies, Quantity surveyor, Performance Indicators, Namibia.

Introduction

In the construction industry, risk management plays a crucial role. It involves identifying, evaluating, and prioritising risks and then coordinating actions to reduce, monitor, and control the likelihood or effect of unfavorable occurrences (Divya Sankar, Shashikanth, & Mahender, 2022). Building projects are vulnerable to a number of hazards including legal, financial, safety, and environmental issues (Szymański, 2017). The building industry in Namibia is not exempt from these challenges frequently facing problems that include overspending, delays, and quality issues, all of which are made worse by a lack of effective risk management strategies (Shifidi, 2010).

In the construction business, quantity surveyors are essential because they oversee contracts and expenses, making sure that projects are finished on time, on budget, and to the necessary standards (Royal Institute of Chartered Surveyors, 2018). Their responsibilities have always centered on financial management and cost estimation (Adafin, Rotimi & Wilkinson, 2020). Since building projects are becoming more complicated, quantity surveyors now play a bigger role in risk management. Even with this progress, there is still a lack of incorporation of appropriate risk management strategies into their processes, especially in Namibia. This disparity is reflected in the inadequate resources and training that quantity surveyors in the area have access to, which leads to less than ideal risk management results (Gbajobi et al., 2018). The discrepancies show how stronger context-related risk management procedures are required (Royal Institute of Chartered Surveyors, 2018).

Therefore, the aim of this study is to evaluate the effectiveness of the risk management strategies utilised by quantity surveyors within contract administration in Namibia. Quantity surveyors play a crucial role in risk management throughout the building project lifecycle, especially in developing nations

where resource constraints, legal requirements, and outside economic forces frequently present specific difficulties as highlighted by Gbajobi et al., 2018. The primary objectives are to determine the importance of risk management strategies utilised by quantity surveyors and to evaluate the effectiveness of the risk management strategies relative to performance expectations. By focusing on these objectives, the study will advance knowledge of the risk management strategies as well as offer suggestions for future developments (Gbajobi et al., 2018). Construction risk management supports the idea that effective risk management may result in increased project performance, less financial losses, and higher industry standards overall (Olawumi & Ayegun, 2016; Shifidi, 2010).

The next section of the paper will focus on the theoretical framework. Following this risk management strategies utilised by quantity surveyors and effectiveness of the risk management strategies will be reviewed. The research methodology will be discussed covering research design, sampling design, instrument design, data collection, and data analysis. After this, the less-than-ideal analysis, interpretation, presentation, and discussion will be undertaken. Finally, the paper will present conclusions based on the objectives, list recommendations, and identify areas for further study not covered in this research

Literature Review

Theoretical framework

The theoretical framework for examining the effectiveness of risk management strategies utilised by quantity surveyors in Namibia is grounded in two interrelated theories namely the risk management theory and the performance measurement theory. These theories provide a comprehensive understanding of risk management within the context of construction projects, particularly focusing on the unique challenges and conditions. The risk management theory underpins the study and is especially applicable to the construction sector, since projects are frequently challenged by a variety of uncertainties, including fluctuating material prices, directing regulations, and unanticipated environmental circumstances (Lee & Eid, 2018). In addition, the performance measurement theory resolves to signify the importance of measurements and indicators used to assess the efficacy of risk management techniques (Bourne, Melnyk & Bititci, 2018). This notion is critical to evaluating the efficacy of the tactics used by Namibian quantity surveyors. This study may identify which risk management techniques are most successful in enhancing project results by examining these KPIs (Dufvelin, 2018). This theoretical framework offers a thorough method for examining the efficacy of risk management strategies used by quantity surveyors in Namibia by merging the theories of risk management and performance measurement. The research intends to provide comprehensive knowledge of how these theories may successfully underpin risk response strategies in the particular context of Namibian construction projects, eventually promoting the industry's profitability and sustainability.

Risk management strategies utilised by quantity surveyors

Due to its unpredictable material prices, labour scarcity, shifting regulations, and effects on the environment, the construction sector is risky by nature (Adafin, Rotimi & Wilkinson, 2020). Quantity surveyors are in a unique position to manage these risks throughout the project lifecycle because of their experience in cost estimating, project management, and contract administration (Adafin, Rotimi & Wilkinson, 2020). The purpose of the risk monitoring and regulation strategy is to provide oversight on the execution of responses, identify areas that require more action, and assess the effects of any changes that may be made to the program's risk profile (Royal Institute of Chartered Surveyors, 2018). When risk management is applied to identify and control hazards from the outset of a project, it can minimise their likelihood and effects or increase their efficacy. It ought to be applied throughout the course of the project (Royal Institute of Chartered Surveyors, 2017). From the perspective of quantity surveying, risk management involves three steps: first, identifying potential risks (e.g., through risk assessments, stakeholder consultations, or past project data review), second, developing specific techniques or actions (e.g., contingency planning, insurance, budget adjustments), and third, monitoring and adjusting strategies throughout the project lifecycle to ensure risk is managed effectively (Gbajobi et al., 2018; Royal Institute of Chartered Surveyors, 2018). According to Kang et al. (2015), the monitoring phase should be continuous and subject to yearly or biannual assessments for projects than run for more than a year. Shorter projects frequently call for more frequent evaluations, possibly weekly or monthly to make sure things are moving along as planned and to enable unforeseen alterations.

Managing risks during the construction phase has become increasingly challenging in project management due to the growth in project sizes and complexities (Adafin, Rotimi & Wilkinson, 2020). The key of any risk management process is to maximise benefits while reducing the impact of a potentially hazardous circumstance (Gbajobi et al. ,2018).After a literature review, the risk management strategies shown in Table 1 are utilised by quantity surveyors:

Table 1: Risk management strategies

Risk Management Strategies	Description	Sources
Contingency Allowance	A budget reserved for unanticipated project expenses, usually used to pay for unforeseen costs. It lessens the effect of uncertainty.	Akinradewo et al. (2019)
Retention	A portion of the contract amount withheld until the project is finished in order to monitor contractor performance and address any issues that may come up.	Bolton et al. (2022)
Liquidated Damages	A certain amount stipulated in a contract that the contractor is required to pay in the event that they are unable to finish the work as promised or on schedule.	El Bakey (2018)
Written instructions	Formal instructions given to a contractor by a client or principal agent that specify certain tasks to be completed or project modifications.	Szymański (2017)
Insurances	Policies obtained to guard against possible risks during a construction project, including as property damage, third-party liability, or worker injury.	Vasilyeva & Okrepilov (2018); Conditions et al. (2015)
Extension of Time claim	A formal request, sometimes accompanied by supporting documents, made by a contractor to extend the project deadline because of unanticipated delays.	Shabbar, Ullah, Ayub, Thaheem, & Gabriel (2017)
Progress meetings, technical meetings, Interim technical/cost reviews and strategic/problem solving meetings	Progress meetings: Regularly planned gatherings of project participants to go over the project's present state, evaluate work that has been performed, and discuss any impending tasks or problems.	Gbajobi et al. (2018)
	Technical meetings: In-depth talks on technical difficulties, requirements, and specialised design or construction concerns with the participation of engineers, architects, or specialists.	
	Interim Technical/Cost Reviews: Regular assessments carried out during a project to appraise expenditures in relation to the budget and analyse technological advancements, guaranteeing the project remains on schedule.	
	Strategic/Problem-solving meetings are held to discuss important project risks, difficulties, or strategic choices that call for feedback from leadership and important stakeholders.	
Quality control/assurance test	Procedures and testing done to make sure a project's materials and workmanship adhere to the necessary requirements and standards.	Conditions et al. (2015)
Performance Guarantee	A security that guarantees the contractor will finish the project in accordance with the terms set out, typically in the form of a bond or financial guarantee.	Hassan & Adnan (2018)
Price Adjustments	Adjustments made to the contract price to reflect cost variations, such as adjustments to the scope of work, labour rates, or material prices.	Olatunji et al. (2018); Mehta et al. (2018)
Defect's liability period	A time frame following project completion within which the contractor is in charge of fixing any problems or flaws that emerge.	Conditions et al. (2015); Oluwole, Razak, & Oluwole (2012)

Despite improvements in risk management strategies and tools, quantity surveyors frequently find it difficult to put them into practice (Gbajobi et al., 2018). Typical difficulties consist of quantity surveyors finding it difficult to carry out thorough risk assessments and instituting mitigation plans due to resource restrictions. To ensure that quantity surveyors have access to the latest methods and resources for risk management, they must continue their professional development. The adoption of new technology and risk management approaches can be delayed by organisational resistance and reluctance to change. Finally, quantity surveyors must keep updated on industry standards and legal requirements in order to navigate the complicated regulatory landscape (Osazuwa & Oke, 2020).

Performance expectations measure the effectiveness of risk management

The efficacy of risk management may be assessed by performance indicators (Mesároš, Behúnová, Mandičák, Behún, & Krajníková, 2021). Performance measurement is a constant and methodical process of obtaining trustworthy data on a project's performance and identifying the elements that impact effectiveness, whereas project performance management makes use of the data gathered. (Mbugua, Ajwang', & Winja, 2021). According to Mbugua et al. (2021) performance indicators are components that significantly influence the success or failure of a construction project and should be identified in order to increase construction productivity. The main source of traditional performance issues is that it uses indicators based on unchangeable acts and results, which means it lags behind (Kundi & Unab, 2014). Several Key Performance Indicators (KPIs) were identified following a review of the literature. Construction project performance indicators are presented and defined in Table 2.

Table 2: Performance indicators

Performance indicator	Review	Sources
Labor productivity	Performance indicators are an excellent instrument for monitoring job efficiency and project progress. You may re-evaluate and make necessary modifications to maintain the project on schedule and under budget by analysing the performance of workers and other participants on the building site. By focusing on project objectives, performance KPIs help project managers assess how successful the project was.	Mani (2015); Bortoluzzi, Carey, McArthur & Menassa (2018)
Quality	Enhancing the project's integrity is essential to reducing future alterations. Setting a high priority for quality indicators is essential to keeping the project under budget and on schedule. Designers and developers are among the quality assurance staff members in the majority of multinational organisations. Having exceptionally talented individuals on your team may help ensure a high percentage of managed to pass tests, as passing all assessments is crucial. Knowing how long your projects will last can also help you make less revisions and rework.	Mani (2015); Shaikh & Darade (2017)
Safety	Safety on the building site must be prioritised for both immediate and long-term benefits. Participating in safety measures lowers your chances of encountering challenges like expensive insurance premiums or other unanticipated costs. Recognising the importance of safety as a KPI is essential for maintaining employee safety while reducing costs and fostering satisfaction and productivity. Longer costs and less dangers are associated with a safer place. Should issues emerge, your project may have delays in terms of budget and timeline. In addition, safety concerns might lead to higher insurance costs. Therefore, preserving employee productivity and cutting costs require that you recognise and embrace your safety record.	Mahmoud, Ahmad, Yatim, & Dodo (2020); Karanikas, (2016)
Client Satisfaction	Asking clients directly is one of the best ways to assess how outstanding the entire outcome is. One is performing well in the eyes of a clients if one's sense of fulfilment percentage is high. Furthermore, you could feel safe and at ease knowing that you are meeting their needs and accomplishing the goals you have set for them. Maintaining a respectable clientele of happy clients is essential. Focusing on employee happiness and zeal at the same time is crucial.	Sibiya, Aigbavboa, & Thwala (2015); Mani (2015)
Time and Cost	Building costs and schedules are important factors to take into account. One can be positive that the client is satisfied but you cannot determine how much the complete project will end up costing. To find out how much it will cost to accomplish these goals, sum up all of the expenses. Also, one could want the cost of construction to be much less than the investment one makes in order to	Mani (2015); Mbugua et al. (2021)

	generate money from it. Building project length is connected to this factor since it often aligns with the costs. A project's cost increases with its duration of completion.	
Employees	Employee satisfaction is a key performance indicator (KPI) that directly impacts productivity and organisational sustainability. Content and recognised employees are more likely to stay in their roles, work harder, and perform better over time. Evaluating both job satisfaction and development is as important as tracking output. Higher employee morale leads to lower turnover, and supported, engaged workers contribute positively to project outcomes while maintaining energy and productivity.	Mani (2015)

Research Methodology and Method

Design

Based on a similar study done by Yogeshwaran et al. (2018) the philosophy for this research was positivism. Saunders et al., (2016) reports that positivists focus on observable social realities, and their research often leads to concepts similar to those in physical and natural sciences. In addition, they develop a research strategy that involves gathering data based on existing theories to formulate hypotheses, which are then tested and validated. As used by a similar study by Gbajobi, Odediran and Adegoke (2018) the methodological choice for this research was quantitative. Quantitative research is centered on measuring and quantifying data and is used to identify patterns, draw conclusions, verify causal relationships, and guide larger groups (Saunders et al., 2016).

Sampling

The sampling frame, sampling methods, and size determination were all part of the sampling design. In contrast, the sample frame consisted of Windhoek-based registered quantity surveyors employed by registered consulting firms with The Institute of Namibian Quantity Surveyors (INQS). The research employed census sampling which involved collecting data from every member of the target population due to the low population of registered quantity surveying consultants (Saunders et al., 2016). The study's target population consisted of 77 registered quantity surveyors according to INQS database.

Instrument design and data collection

The data collection instrument employed was a questionnaire survey. The design of this instrument included a section dedicated to demographic questions, alongside sections tailored to address each research objective using Likert scale type questions. The questionnaire was intended to gather information such as current practices in risk management strategies, and the most effectiveness of these methods *vis-a-vis* performance expectations. After the questionnaire was developed, a pilot test was carried out to evaluate the validity, reliability, and clarity of the questions prior to the questionnaires being distributed to the selected firms. After minor modification of the questionnaire after the pilot test it was distributed to the selected firms which were subsequently collected, and data analysis commenced.

Data analysis

All objectives were analysed using Statistical Package for the Social Sciences (SPSS) of 2022. The objectives data was analysed by use of Cronbach's alpha and the evaluation scale (Tavakol & Dennick, 2011), RII and the evaluation scale (Gündüz, Nielsen, & Özdemir, 2013) as well as Pearson correlation and the evaluation scale (Bhandari, 2019).

A measure of internal consistency called Cronbach's alpha shows how effectively a collection of items or variables captures the essence of a single, unidimensional latent concept. The typical interpretation of the Cronbach's alpha evaluation scale is as follows: $\alpha \geq 0.90$: Excellent (high reliability), $0.80 \leq \alpha < 0.90$: Good (reliable) $0.70 \leq \alpha < 0.80$: Acceptable (moderate reliability), $0.60 \leq \alpha < 0.70$: Questionable (low reliability), $0.50 \leq \alpha < 0.60$: Poor (unreliable), $\alpha < 0.50$: Unacceptable (very low reliability). These thresholds are guidelines and may vary depending on the field of study or context (Wadkar et al., 2016).

When the Cronbach's alpha value exceeds the 0.70 threshold, it implies the data can be considered reliable. (Izah, Sylva & Hait, 2023).

According to Gbajobi et al. (2018) $RII = \frac{\sum W}{N \cdot A}$, Where W= the weight given to each factor by the respondents ranges from 1 to 5, (where "1" is very high, "2" is high, "3" is moderate "4" is low and "5" is very low), A = highest weight (i.e., 5 in this case) and; N = the number of responses (p. 127).

Formula: $RII = \frac{\sum W}{N \cdot A}$ (Gündüz, Nielsen, & Özdemir, 2013, p. 135).

Evaluation scale: "not important" < 0.2; 0.2 < "of little importance" ≤ 0.4; 0.4 < "somewhat important" ≤ 0.6; 0.6 < "important" ≤ 0.8; 0.8 < "very important" ≤ 1 as modified from Gbajobi et al. (2018).

A normality test was done to confirm the use of the parametric Pearson correlation test. The Kolmogorov–Smirnov test, for a sample of less than 50, result of a p-value of > 0.05 supported this (Hossen et al., 2020). The Pearson correlation coefficient (r) measures the strength and direction of the linear relationship between two variables. The evaluation scale for Pearson correlation is typically interpreted as follows: r = 1: Perfect positive correlation, 0.70 ≤ r < 1: Strong positive correlation, 0.50 ≤ r < 0.70: Moderate positive correlation, 0.30 ≤ r < 0.50: Weak positive correlation, 0 ≤ r < 0.30: Very weak or negligible positive correlation, r = 0: No correlation, -0.30 < r ≤ 0: Very weak or negligible negative correlation, -0.50 < r ≤ -0.30: Weak negative correlation, -0.70 < r ≤ -0.50: Moderate negative correlation, -1 < r ≤ -0.70: Strong negative correlation, r = -1: Perfect negative correlation. These guidelines help interpret the strength of the relationship between the variables (Hossen et al., 2020).

Results and Discussion

Profile of respondents and response rate

Table 3: General profile of the respondents

Respondents' Particular	Frequency	Percentage (%)
<u>Professional Qualification</u>		
Registered Quantity Surveyor	10	38
Quantity in training	16	62
TOTAL	26	100
Respondents' Particular	Frequency	Percentage (%)
<u>Years of experience in construction industry</u>		
0-5	11	42
6-10	13	50
11-15	1	4
16-20	1	4
Above 20	0	
TOTAL	26	100
<u>Educational Level</u>		
Diploma	3	12
Degree	20	77
Post Grad. (MSc, MPhil, PHD)	3	12
TOTAL	26	100

The research aimed to collect data from 39 participants but managed to gather responses from 26, achieving an 34% low response rate. As shown in Table 3, the demographic data reveals that 38% are registered quantity surveyors, and 62% are in training. Experience levels vary, with 42% having 0-5 years and none exceeding 20 years. Educational qualifications are high, with 77% holding degrees. This diverse and experienced sample adds to the study's validity.

Results

Importance of risk management strategies utilised by quantity surveyors

Table 4 presents a Cronbach's alpha value of 0.856, above the 0.70 threshold and supporting the data's reliability (Izah, Sylva & Hait, 2023).

Table 4: Cronbach reliability test results for the importance of the Risk Management Strategies (RMS) utilised by quantity surveyors

Reliability Statistics		
Cronbach's Alpha Based on		
Cronbach's Alpha	Standardised Items	N of Items
.856	.851	11

Table 5 presents the findings of an analysis conducted to determine the relative significance of risk mitigation strategies employed by quantity surveyors.

Table 5: RII for the effectiveness of RMS utilised by quantity surveyors

RMS	RII	Evaluation	Ranks
Extension of time claims	0.577	Somewhat important	1
Liquidated damages	0.538	Somewhat important	2
Contingency allowances	0.523	Somewhat important	3
Progress meetings, technical meetings, Interim technical/cost reviews and strategic/problem solving meetings	0.485	Somewhat important	4
Price adjustments	0.477	Somewhat important	5
Insurances	0.446	Somewhat important	6
Quality control/assurance test	0.438	Somewhat important	7
Performance guarantee	0.438	Somewhat important	7
Written instructions	0.423	Somewhat important	9
Defect liability period	0.423	Somewhat important	9
Retention	0.262	Of little importance	11

Table 5 makes it clear that, among quantity surveyors in the construction industry, extending time claims is the most crucial risk management strategy. This technique was scored best with a RII of 0.577. Additionally, with a RII of 0.538, liquidated damage was regarded as the second most popular risk management technique, while contingency allowances came in third with a RII of 0.523. The risk management strategy for contingency allowances is as follows: written instructions, defect liability period, performance guarantee, insurances, interim technical/cost reviews, progress meetings, technical meetings, insurances, and interim technical/cost reviews and strategic/problem solving meetings (RII= 0.485, 0.477, 0.446, 0.438, 0.423, 0.423 respectively). Retention is the least utilised risk management strategy with a RII of 0.262.

Effectiveness of risk management strategies relative to performance indicators

The findings of a study conducted to assess the effectiveness of the risk management strategies employed by quantity surveyors are shown in Table 6 below.

Table 6: Pearson correlation for performance indicators most affected by RMS utilised by quantity surveyors

RMS		Performance indicators						
		Labour productivity	Quality	Safety	Client Satisfaction	Time	Cost	Employees
RMS 1 – Contingency allowances	Pearson	0.218	0.338	0.089	0.235	-0.077	0.146	0.122
	Sig. (2-tailed)	0.284	0.091	0.664	0.247	0.710	0.476	0.553
RMS 2 – Retention	Pearson	0.071	0.267	0.029	0.296	-0.347	-0.179	0.002
	Sig. (2-tailed)	0.732	0.187	0.888	0.142	0.082	0.382	0.990
RMS 3 – Liquidated damages	Pearson	0.114	0.240	0.047	0.245	-0.054	-0.009	0.134
	Sig. (2-tailed)	0.580	0.238	0.821	0.228	0.792	0.964	0.512
RMS 4 – Written Instructions	Pearson	0.058	-0.034	0.038	0.206	0.107	-0.131	0.069
	Sig. (2-tailed)	0.780	0.870	0.855	0.313	0.602	0.523	0.737
RMS 5 – Insurances	Pearson	0.266	0.244	0.304	0.249	-0.055	-0.293	0.269
	Correlation							

	Sig. (2-tailed)	0.189	0.230	0.131	0.221	0.788	0.146	0.184
RMS 6 – EOT claims	Pearson	-0.062	0.136	-0.141	0.211	-0.431 [*]	-0.182	-0.104
	Correlation							
	Sig. (2-tailed)	0.765	0.509	0.491	0.301	0.028	0.374	0.614
RMS 7 – Progress meetings, technical meetings, interim technical/cost reviews and strategic/problem solving meetings	Pearson	0.158	0.194	-0.015	0.509 ^{**}	-0.015	0.043	0.171
	Correlation							
	Sig. (2-tailed)	0.440	0.342	0.940	0.008	0.940	0.836	0.403
RMS 8 – Quality control/ Assurance test	Pearson	0.383	0.183	0.430 [*]	0.234	0.034	-0.163	0.306
	Correlation							
	Sig. (2-tailed)	0.053	0.370	0.028	0.250	0.870	0.426	0.129
RMS 9 – Performance guarantee	Pearson	0.094	-0.034	0.228	-0.063	-0.128	-0.396 [*]	0.071
	Correlation							
	Sig. (2-tailed)	0.649	0.867	0.262	0.760	0.534	0.045	0.732
RMS 10 – Price adjustments	Pearson	0.194	0.133	0.166	0.153	-0.187	-0.133	0.072
	Correlation							
	Sig. (2-tailed)	0.342	0.518	0.418	0.457	0.361	0.517	0.728
RMS 11 – Defect liability period	Pearson	0.332	0.342	0.284	0.423 [*]	-0.032	0.006	0.306
	Correlation							
	Sig. (2-tailed)	0.097	0.087	0.160	0.031	0.875	0.975	0.129

*. Correlation is significant at the 0.05 level (2-tailed).

The Pearson correlation is a parametric test which means that the data was normally distributed. RMS 7 and client satisfaction were moderately positively correlated ($r = 0.509$, $p = 0.008$), which indicates that as the frequency or effectiveness of these meetings increases, client satisfaction tends to increase. RMS 8 and safety were weakly positively correlated ($r = 0.430$, $p = 0.028$) which indicates that as the effectiveness or frequency of quality control/assurance tests increases, there is a slight increase in safety. RMS 11 and client satisfaction were weakly positively correlated ($r = 0.423$, $p = 0.031$) which indicates that as the length or effectiveness of the defect liability period increases, client satisfaction increases slightly. RMS 6 and time were weakly negatively correlated ($r = -0.431$, $p = 0.028$) which indicates that EOT claims negatively affect timeous delivery of projects. RMS 9 and cost were weakly negatively correlated ($r = -0.396$, $p = 0.045$) which indicates that as the performance guarantee increases (in terms of amount or strictness), the cost slightly decreases, but the relationship is very small.

Discussion

This section will discuss the results presented on the important risk management strategies and the effectiveness of the same relative to the performance indicators.

Important risk management strategies

Although Namibian Qs have a solid understanding of risk management, there are still large gaps in their practical implementation as can be seen in Table 5 with all results of RII being quite low, which is consistent with the challenges in developing countries documented in earlier research by Odumabo (2016). With the greatest Relative Importance Index (RII) of 0.577, the results show that quantity surveyors in the construction industry agree that extending time claims is the most effective risk management strategy. The results support the claim made by Yoke-Lian, Hassim, Muniandy, and Mee-Ling (2012) that the unforeseen, complex, and constantly changing nature of the construction sector caused delays to become the norm. This supports Yoke-Lian, Hassim, Muniandy, and Mee-Ling's (2012) claim that extensions of time (EOT) are now frequently used in construction projects, especially when standard contract forms are used, and that they are regarded as reasonable delays in standard construction contracts. The over-reliance on extension of time (EOT) claims can have detrimental consequences on other performance measures, most notably cost, despite the fact that EOT claims are an effective risk management method for handling delays. Project durations are usually extended when EOT claims increase, which increases overhead expenses, prolong the use of resources, and

may lead to cost overruns. This is because longer project timelines frequently translate into greater labour, material, and equipment costs, which can strain project budgets (Szymański, 2017). With a RII of 0.538, liquidated damages were the second most often used technique. Schedule overruns are frequent in the construction industry, and it is anticipated to be challenging to accurately determine the losses incurred by the impacted party. In order to counter that, the liquidated damages (LD) clauses in the contract set a predetermined amount for failure to complete the building work by the scheduled date (Assaad & Abdul-Malak, 2020). Contingency allowances in third place with an RII of 0.523, the project team members ought to be concerned about determining an appropriate amount or percentage allowance to handle unforeseen changes in the building project budget. Technically speaking, contingency provision has never been sufficient or predictable (Bello & Odusami, 2013).

Effectiveness of risk management strategies relative to performance indicators

The correlation coefficient relationship between the risk management strategies and performance indicators shows both positive and negative correlations. There was a positive correlation ($r = 0.509$, $p = 0.008$) between client satisfaction and progress meetings, technical meetings, interim technical/cost reviews, and strategic/problem-solving meetings. The reason is that these interactions guarantee successful resolution of problems, transparent communication, and clear communication. Regular participation in these sessions fosters trust, sets clear expectations, and proactively addresses problems, all of which increase client satisfaction (Wu et al., 2017). Another positive correlation was between quality control/assurance tests and safety ($r = 0.430$, $p = 0.028$). These tests help identify and mitigate potential hazards by ensuring that products or processes meet safety standards. Regular and thorough testing enhances reliability and minimises risks, thereby creating a safer environment for users and workers alike (Bhattacharjee, 2018). The third positive correlation that was observed was between the defect's liability period and client satisfaction ($r = 0.423$, $p = 0.031$), as it provides clients with assurance that any post-completion issues will be promptly addressed. This period fosters confidence in the quality of work and promotes long-term trust, leading to increased client satisfaction (Kariya, 2016). One of the negative correlations identified was between extension of time and time ($r = -0.431$, $p = 0.028$), granting extensions typically results in delays in the overall project timeline. These delays can disrupt schedules and lead to inefficiencies, ultimately extending the time required to complete the project (Rachid, Toufik, & Mohammed, 2019). The other negative correlation observed was between performance guarantees and cost ($r = -0.396$, $p = 0.045$). Implementing a performance guarantee often leads to additional expenses for ensuring compliance with the required standards (Seboru, 2015). The rest of the risk management strategies had insignificant correlations with performance indicators. This confirms the premise that risk management strategies implemented in Namibia are ineffective, as previously revealed by Shifidi (2010). Namibian risk management strategies are ineffective due to elements like economic instability, scarce resources, and comprehending regulatory frameworks that make proactive risk management challenging. Unlike in more developed nations, these methods are also less likely to be implemented successfully due to a lack of industry experience and access to advanced technology (Lee & Eid, 2018). Since then, progress on effective implementation or alternative strategies is lacking. Satisfying performance indicators of labour productivity, quality and employee job satisfaction is still unresolved. These findings reinforce the need to enhance contextual research and development in risk management of construction projects.

Conclusion, Recommendations and Limitations

The effectiveness of risk management strategies utilised by quantity surveyors in Namibia provides a number of important insights related to the impact of poorly managed uncertainties on project outcomes. The aim of this study was to evaluate the effectiveness of the risk management strategies utilised by quantity surveyors within contract administration in Namibia. The primary objectives were to determine the importance of risk management strategies utilised by quantity surveyors and to evaluate the effectiveness of the risk management strategies relative to performance expectations. Key findings show that Extension of time claims, Liquidated damages and Contingency allowances are the most important risk management strategies. However, the overall level of the importance is concerning, as most of them were considered somewhat important. Consequently a few significant correlations were determined: client satisfaction and progress meetings, technical meetings, interim technical/cost reviews, and strategic/problem-solving meetings; quality control/assurance tests and safety; the defects liability period and client satisfaction; extension of time and time; performance guarantees and cost.

Comprehending the legal and economic landscape locally are essential for enhancing risk management strategies. Through the alignment of these expectations with risk management strategies, quantity surveyors may guarantee enhanced project outcomes and more precise evaluations. The study reveals the importance of enhancing communication and continuously refining risk management practices for achieving better results in future projects. The following recommendations are suggested:

- Future research may identify best practices specific to the Namibian setting and offer useful insights into the efficacy of various strategies. In order to obtain comprehensive information, researchers should work in conjunction with construction enterprises and quantity surveyors.
- Professional bodies and academic establishments to collaborate in order to create and carry out risk management training initiatives.
- Organisations should place a high priority on the professional development of its quantity surveyor and provide them with the resources they need to properly manage risks.

A major limitation of the study was its low response rate, which may have impacted the representativeness and generalisability of the findings. Despite this, addressing the determined gaps will enhance the overall effectiveness of risk management practices in future projects. To provide more representative and broadly applicable results, future research should concentrate on expanding the sample size and enhancing response rates. Research may also examine how various project sizes and types affect risk management strategies. Further studies could look into how modern techniques and new technologies affect risk management in building projects. By addressing these issues, risk management strategies will be more adaptable and effective overall for a wider range of projects.

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Evaluating Discrepancies Between Existing and Expected Sustainable Construction Competencies Among Namibian Quantity Surveyors: a Pilot Study

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Abstract

This paper sought to determine the gap between the existing and expected sustainable construction competencies of quantity surveyors in Namibia to reveal interventions that include specialised training in sustainable construction competencies, integrating sustainability into education curricula, enhancing continuous professional development, and promoting green building certifications to align with international sustainability standards. The study employed a positivist philosophy, collecting data from 261 practising consultants and contractor quantity surveyors in Namibia through a pilot online questionnaire survey. The target population included quantity surveyors registered with the Institute of Namibian Quantity Surveyors and those working for construction companies registered with the Construction Industries Federation of Namibia, ensuring diverse perspectives. The study further utilised mean score and standard deviation and one sample T-test of means to determine the discrepancies between Namibian quantity surveyors' existing and expected sustainable construction competencies. A significant gap in knowledge related to sustainability-related competencies, life cycle costing, and energy efficiency among Namibian quantity surveyors was determined. There is also a notable deficiency in formal education and ongoing training in sustainability, which hinders the adoption of sustainable construction competencies by quantity surveyors in the Namibian construction industry. The limited availability of literature on the competencies of quantity surveyors concerning sustainable construction constrained the research scope and may affect the findings' generalisability. Additionally, while sufficient for exploratory analysis, the small sample size may not fully represent the entire population of quantity surveyors in Namibia. The study recommends targeted training programs and continuous education to address the lack of sustainable construction competencies. Short-term life cycle costing and energy efficiency certifications, along with sustainability-focused courses in quantity surveying education, can help bridge the gap. These findings can also guide the construction industry's creation of sustainability-focused professional standards and policies. This research paper exposes the gaps between the existing and expected sustainable construction competencies of Namibian quantity surveyors. This provides a foundation for policymakers and educators to develop targeted interventions that address the identified competency gaps.

Keywords: Sustainable Construction, Competency, Quantity surveyor, Sustainability.

Introduction

The construction industry, while essential to global economic growth and infrastructure development, is one of the most significant contributors to environmental degradation (Wang & Dong, 2019). It is one of the most environmentally detrimental sectors, responsible for approximately 30% of global greenhouse gas emissions and significant resource consumption (Kamath et al., 2019). Namibia faces a unique set of sustainability hurdles, including water scarcity, energy insecurity, and the growing impacts of climate change (Maio et al., 2016). Against this backdrop, the role of sustainable construction has come to the forefront as an essential paradigm for reducing the sustainability deficits of building projects. Sustainable construction involves the integration of economic, social, and environmental factors

throughout a building's lifecycle, from design and construction to operation and deconstruction (Kibert, 2016). The goal is not merely to minimise negative impacts but also to maximise long term benefits in areas such as energy efficiency, resource conservation, and social well-being (Kibert, 2016; Ogunmakinde et al., 2017).

Quantity surveyors, key professionals in cost control, contract management, and procurement within the construction industry, are uniquely positioned to influence sustainable construction outcomes (Bolade-Oladepo & Oladipo, 2020). Despite this, the adoption of sustainable construction practices remains limited among quantity surveyors, largely due to a lack of relevant competencies and formal training (Moyo et al., 2023). Studies have shown that while quantity surveyors in developing countries are increasingly embracing concepts such as life cycle costing and energy efficiency, those from developing countries lag, hindered by insufficient education and training opportunities in sustainable practices (Chigara & Smallwood, 2018; Njere & Moyo, 2018). The primary issue lies in the inadequacy of current training programs, which fail to equip quantity surveyors with the necessary skills to implement sustainable practices effectively. One reason for this failure could be the outdated or insufficient integration of sustainability-related content in educational curriculums and professional training modules (Darko et al., 2018). Additionally, the absence of national policies and incentives that prioritise sustainability further hampers efforts to build relevant competencies in the industry (Olawumi & Chan, 2019). This gap in training and education is a major obstacle to aligning Namibia's construction sector with global sustainability standards, and addressing it is critical to advancing both the nation's sustainability goals and the competitiveness of its construction industry. For the purposes of this study, existing competencies refer to the current knowledge, skills, and practices that Namibian quantity surveyors possess regarding sustainable construction. In contrast, expected competencies are the ideal set of knowledge, skills, and behaviours that quantity surveyors should have to effectively contribute to sustainability goals in the construction industry

While various studies (Chan et al., 2018; Omotayo et al., 2023; Zulu et al., 2023) have explored sustainable construction competencies, there remains a lack of detailed analysis focused specifically on quantity surveyors in Namibia and their unique challenges. More importantly, existing literature often fails to question why current training programs do not adequately cover key sustainability competencies, and how they can be restructured to address these gaps. This study aims to bridge this gap by identifying the existing and expected competencies of Namibian quantity surveyors in relation to sustainable construction and extrapolating the interventions needed to enhance these competencies. Specifically, this research focuses on the knowledge, skills, and attitudes necessary for integrating sustainability into construction processes, with a particular emphasis on life cycle costing, resource management, and energy efficiency (Kibert, 2016; Omotayo et al., 2023). Although this pilot study offers valuable preliminary insights, further research with a larger sample is currently being conducted to confirm these findings and develop more comprehensive strategies for enhancing sustainable construction competencies in Namibia. This study seeks to address the following objectives:

- To identify the existing competencies for sustainable construction and identify the expected competencies for sustainable construction
- To examine the gap between the existing and expected sustainable construction competencies of Namibian quantity surveyors.

Literature Review

Sustainable construction concept

Sustainable construction is a multidimensional approach that encompasses the entire lifecycle of a building, from the extraction of materials to disposal, aiming to minimise the environmental footprint of construction activities (Murray, 2019). This concept extends beyond the materials and processes used in building construction to include energy and water consumption, as well as the impact of construction activities on human health and the environment (Kibert, 2016). The physical distribution and relationships of buildings and infrastructure, as well as the ensuing energy consumption profiles because of planning decisions, further complicate the picture (Kibert, 2016). Implementing sustainable construction thus requires the interaction of public policy (regulations, incentives, and disincentives); the real estate, finance & insurance industries; the institutions of higher learning, consulting firms, and construction companies in educating, training, and employing various stakeholders in this complex industry known as the construction industry (Det Udomsap & Hallinger, 2020).

Countries globally have adopted frameworks to promote sustainable construction. For example, the European Union focuses on building energy efficiency, while the U.S. uses the Leadership in Energy and Environmental Design (LEED) certification as a sustainability benchmark (Alotaibi et al., 2019). However, the adoption of such practices in developing countries remains limited due to financial constraints, insufficient training, and weak regulatory frameworks (Cebrián et al., 2020). These initiatives have significantly advanced the global adoption of sustainable construction, although their implementation in developing countries remains limited (Moyo et al., 2023). In developing countries, the adoption of sustainable construction practices is hindered by various challenges. While global initiatives like LEED have set high standards, but developing regions face challenges due to limited funds, inadequate training, and weak regulations (Zhang et al., 2019). The construction industry in many developing countries has been slow to adopt sustainability initiatives, largely due to the lack of skilled professionals, including quantity surveyors, who are critical in ensuring cost-effective and environmentally responsible project execution (Ametepey & Aigbavboa, 2015). A key component of sustainable construction is life cycle costing (LCC), a method that assesses a building's total cost, including environmental and economic factors over its lifespan and promotes long-term sustainability investments, reducing costs and environmental impact (Murray, 2019). While common in developed countries, LCC is underused in developing regions due to short-term financial constraints (Aigbavboa et al., 2017). Sustainable construction emphasises minimising waste through reuse and recycling. While developed nations often recycle construction waste, developing countries face barriers like inadequate infrastructure and a lack of incentives (Ogunmakinde et al., 2017). Resistance to change and reliance on resource-intensive methods also persist (Zhang et al., 2019). Despite these challenges, sustainable construction offers economic benefits, such as lower operating costs through improved energy efficiency (Kibert, 2016). To fully integrate these practices, stakeholders must be equipped with the skills and knowledge needed for effective implementation (Zhang et al., 2019).

The role of quantity surveyors and sustainable construction competencies

Quantity surveyors play a pivotal role in the construction industry, particularly in promoting sustainable construction practices. As cost consultants and contract managers, they are responsible for the financial viability and cost control of construction projects, which places them in a unique position to influence sustainability decisions throughout the project lifecycle (Olawumi & Chan, 2020). While traditionally their role focused on financial management, quantity surveyors are increasingly being called upon to integrate sustainability principles into their work, encompassing environmental, social, and economic considerations (Omotayo et al., 2023).

Quantity surveyors are critical in promoting the use of sustainable materials and practices. Through their involvement in procurement, they can influence the selection of eco-friendly materials, such as recycled or renewable resources, and ensure that these materials align with both budgetary and sustainability goals (Ametepey & Aigbavboa, 2015). In this regard, quantity surveyors' ability to align project costings with sustainable material selection is crucial in driving the shift toward greener construction practices. The integration of Building Information Modelling (BIM) into quantity surveying further enhances the potential for sustainable construction. BIM is an intelligent, 3D model-based process that provides insight and tools to plan, design, construct, and manage buildings more efficiently (Chen & Baddeley, 2015). Quantity surveyors using BIM can improve sustainability by optimising material use, reducing waste, and enhancing energy efficiency throughout a project's lifecycle (Ma & Luu, 2013). BIM allows for better decision-making related to sustainability by providing accurate data on material quantities, energy consumption, and potential savings, further aligning project goals with environmental considerations (Abubakar et al., 2014). However, the effective involvement of quantity surveyors in sustainable construction requires the development of specific competencies.

Skills such as sustainable cost management, environmental impact assessment, and knowledge of green building standards are increasingly essential for quantity surveyors to lead sustainable projects effectively (Olawumi & Chan, 2020). While some developed countries have integrated these competencies into the training of quantity surveyors, many developing countries still lack comprehensive education and training programs that focus on sustainability (Chigara & Smallwood, 2018). Another key area where quantity surveyors can drive sustainability is through risk management. Quantity surveyors can enhance sustainability by managing risks, including financial risks linked to environmental degradation, resource depletion, and regulatory changes (Omotayo et al., 2023). By incorporating sustainability risks into cost assessments, they help ensure project viability and

compliance with future standards, contributing to resilient, sustainable infrastructure (Ametepey & Aigbavboa, 2015).

The competencies essential for sustainable construction include life cycle costing and assessment, which ensures long-term financial viability (Tony & Luu, 2013), and sustainable materials knowledge, focusing on eco-friendly materials (Dada, 2017). Strategies like carbon footprint reduction and BIM integration promote resource efficiency and waste reduction (Okorie & Musonda, 2020). Sustainable procurement and compliance with regulations ensure ethical sourcing and adherence to standards (Victar et al., 2023). Competencies in health and well-being, stakeholder engagement, and cost-benefit analysis address human impact and financial sustainability (Chandramohan, Perera & Dewagoda, 2022). Knowledge of renewable energy, building certifications, and water efficiency further supports sustainable practices (Tony & Luu, 2013). Finally, urban planning, sustainable deconstruction, and lean principles emphasise minimal environmental impact and efficient use of resources (Gunarathne et al., 2022). The table below summarises the quantity surveying sustainable construction competencies identified during the literature review

Table 1: Sustainable construction competencies

SCC	References
Life cycle costing and assessment	Tony & Luu (2013); Omotayo et al. (2023); Bolade-Oladepo & Oladipo (2020)
Sustainable materials knowledge	Dada (2017); Gunarathne et al. (2022)
Carbon footprint reduction strategies	Okorie & Musonda (2020); Chamikara et al., (2020); Bolade-Oladepo & Oladipo (2020)
BIM and sustainability integration	Olatunji et al. (2021); Omotayo et al., (2023); Tony & Luu (2013)
Sustainable procurement expertise	Victar et al. (2023); Chandramohan et al., (2022); Okorie & Musonda (2020)
Compliance with sustainable construction regulations	Chamikara, Perera & Rodrigo (2020); Omotayo et al., (2023)
Health and well-being considerations	Chamikara, et al., (2020);
Stakeholder engagement skills	Chandramohan et al., (2022); Okorie & Musonda (2020)
Cost-benefit analysis of sustainable practices	Gunarathne et al. (2022); Omotayo et al., (2023); Victar et al. (2023)
Renewable energy integration	Tony & Luu (2013);
Sustainable building certifications	Okorie & Musonda (2020); Gunarathne et al. (2022)
Water efficiency strategies	Chamikara et al., (2020);
Sustainable construction finance	Victar et al. (2023); Omotayo et al., (2023)
Sustainable deconstruction and demolition	Gunarathne et al. (2022); Chamikara et al., (2020); Victar et al. (2023)
Occupant behaviour analysis	Chandramohan et al., (2022)
Sustainable urban planning	Okorie & Musonda (2020);
Sustainability strategy development	Omotayo et al., (2023); Bolade-Oladepo & Oladipo (2020)
Responsible construction practices	Dada (2017)
Lean principles	Chamikara et al., (2020); Gunarathne et al. (2022)

Despite the pivotal role quantity surveyors play in promoting sustainable construction, significant competency gaps remain, particularly in developing countries. A key barrier to the effective involvement of quantity surveyors in sustainable construction is the lack of adequate training in sustainability principles. While some developed countries have integrated sustainability into the training of quantity surveyors, many developing countries lag, with limited education programs available to build these essential skills (Cebrián et al., 2020). In addition to formal education, continuous professional development in areas such as life cycle costing, environmental impact assessment, and knowledge of green building standards is critical to equipping quantity surveyors with the necessary competencies (Pham & Kim, 2019). The lack of training in these areas not only hinders the adoption of sustainable practices but also limits the ability of quantity surveyors to assess and manage sustainability risks, such as the long-term financial implications of resource depletion and regulatory changes (Olawumi & Chan, 2020). The urgency of addressing these competency gaps is evident when considering the future of construction in developing countries. As governments and industries strive to meet global sustainability targets, the demand for professionals skilled in sustainable construction is expected to rise. However,

without comprehensive training programs and stronger policy support, quantity surveyors may be ill-equipped to lead the transition to more sustainable construction practices (Santos et al., 2019).

Research Methodology and Method

This study employed a positivist philosophy to objectively explore the gap between existing and expected sustainable construction competencies among quantity surveyors in Namibia. A quantitative approach was chosen due to its ability to produce measurable and generalisable results, making it the most appropriate method for assessing competencies in a structured and objective manner. This method allows for statistical analysis, which is crucial for identifying patterns, relationships, and gaps in sustainable construction competencies. Additionally, this approach aligns with the study's aim to test predefined hypotheses and quantify the discrepancies between current and expected competencies. This methodology aligns with similar studies in the field, such as Aghimien et al. (2018), which also employed quantitative techniques to assess professional competencies in sustainable construction.

The questionnaire was carefully developed based on a comprehensive review of the literature on sustainable construction competencies, including works by Kibert (2016) and Murray (2019). This review helped identify key competencies that are critical for quantity surveyors in sustainable construction, such as life cycle costing, energy efficiency, and the use of sustainable materials. These competencies were then used to design the specific questions in the survey. The questionnaire was designed in two key sections. Section A focused on the demographic characteristics of the respondents, including gender, type of quantity surveyor (consultant or contractor), highest educational level, and years of experience. Section B explored the gap between the existing and expected sustainable competencies. Respondents were asked to rate implementation of sustainable construction competencies using a 5-point Likert scale, where 1 indicated "Strongly Disagree" and 5 represented "Strongly Agree". The respondents were requested to rate the expected implementation of the same sustainable construction competencies, with the scale ranging from 1 ("Never") to 5 ("Always"). This approach allowed for easy comparison between existing and expected competencies.

The population for this study included quantity surveyors registered with the Institute of Namibian Quantity Surveyors (INQS) and those working for construction companies registered with the Construction Industries Federation of Namibia (CIF), representing the key professionals involved in sustainable construction in Namibia. A census approach was employed for the 77 INQS-registered quantity surveyors and all quantity surveyors working for CIF-registered construction companies, all 184 companies were surveyed. This brought the total expected sample size to 261, combining both populations. However, for this pilot survey, at least 30 valid respondents were expected, which is adequate for inferential statistical analysis (Rahi et al., 2019).

To ensure content validity, the questionnaire was reviewed by three subject matter experts in sustainable construction and quantity surveying. These experts assessed whether the questionnaire adequately covered the key competencies identified in the literature. Additionally, the study targeted only practicing quantity surveyors. This focus ensures that the findings are grounded in real-world professional experiences, enhancing the relevance and applicability of the results (Heale & Twycross, 2015). To assess the reliability of the data collection instrument, the Spearman-Brown's alpha was calculated, with a value of 0.927, indicating that the data collection instrument had excellent reliability, with value above 0.7 considered acceptable (Skinner et al., 2018). For testing the normality of the data, the Kolmogorov-Smirnov (K-S) test was applied, yielding a significance value of > 0.05 indicating that the data distribution was normally distributed and necessitated the use of parametric statistical methods (Razali & Wah, 2011). A one-sample T-test was employed to compare the means of the existing and expected sustainable construction competencies. This test was selected because it allows for the determination of whether the mean gap between existing and expected competencies is statistically significant. The T-test is particularly useful for this study as it assesses whether the observed gap is likely to exist in the broader population or if it occurred by chance (Mishra et al., 2019). The significance threshold was set at 0.05, meaning that any p-value below this threshold would indicate a statistically significant difference between current and expected competencies. Additionally, mean ranking was used to analyse the important sustainable construction competencies identified by the respondents, with the following evaluation scale for agreement: 1.00-1.80 = Very Low, 1.81-2.60 = Low, 2.61-3.40 = Moderate, 3.41-4.20 = High, and 4.21-5.00 = Very High. In addition, where the means were similar, the variable with the higher standard deviation was ranked higher (Moyo et al., 2023). By targeting this specific population, the study aimed to generate practical and actionable insights into the state of

sustainable construction competencies among quantity surveyors in Namibia. The study was conducted in accordance with ethical guidelines, receiving ethical clearance from Nelson Mandela University REC-H (Ref: 1008). Informed consent was obtained from all participants, and anonymity and confidentiality were assured. Participants were informed of the study's purpose and their right to withdraw at any time without penalty.

Research Results

Response rate and the demographics of respondents

A total of 31 responses were received for this pilot study, which provided a valuable dataset for understanding the sustainable construction competencies of quantity surveyors in Namibia. While this represents a smaller sample size, it was still deemed reliable and informative for preliminary analysis. According to Teresi et al. (2022), sample sizes of 10 to 30 respondents are often sufficient in exploratory research and pilot studies, providing enough data for meaningful initial analysis. As shown in Table 2, a significant proportion of the respondents were from the Consultant QS sector, with the remainder being Contractor QS professionals. This distribution aligns with the structure of the Namibian construction industry, where consultancy services tend to dominate sustainable construction practices. Regarding education level, the respondents were highly educated, with a majority holding Honours or bachelor's degrees. A smaller percentage reported having Postgraduate Diplomas or master's degrees, while only a few had achieved the highest level of academic attainment with a Doctorate. This high level of educational qualification indicates that the respondents were well-equipped to engage with the technical concepts related to sustainable construction competencies. When examining work experience, most respondents had 6 to 10 years of experience, making up 44% of the total. A substantial number of respondents also had 0 to 5 years of experience (38%), indicating that the survey covered a balanced range of experience levels, from early-career professionals to those with more seasoned expertise. Although only a small number of respondents reported over 15 years of experience, the pilot study provided sufficient diversity in terms of experience to gauge current and expected competencies in sustainable construction.

Table 2: Demographics of respondents

Demographic variable	Number	Percentage
Construction sector		
Consultant QS	22	71
Contractor QS	9	29
Education level		
Diploma	1	3
Post graduate diploma	0	0
Bachelors	14	45
Honours	10	32
Masters	6	19
Doctorate	0	0
Experience		
0-5 years	11	35
6-10 years	14	45
11-15 years	3	10
More than 15 years	3	10

Mean score and gap between quantity surveyors current and expecting sustainable construction competencies

The mean ranking and standard deviation were used to evaluate the most critical sustainable construction competencies for quantity surveyors, as presented in Table 3. The Cost-benefit analysis of sustainable practices had the highest mean score of 4.39 for existing competencies, with an expected competency mean score of 4.70, indicating its importance and the need for further development. Competencies such as Renewable energy integration and BIM and sustainability integration also scored highly, with mean scores of 4.30, reflecting their significance in sustainable construction practices. Conversely, sustainable building certifications and sustainable urban planning had lower

mean scores for existing competencies (3.17 and 2.91 respectively), suggesting that while these areas are still important, they may currently be less emphasised in professional practice. The standard deviation values indicate a moderate level of variability in the responses, reflecting different levels of emphasis on various competencies across respondents.

Table 3: Mean scores of current and expected sustainable construction competencies

Sustainable construction competencies	Existing competencies mean score	Expected competencies mean score	Standard deviation	Evaluation-Existing Competencies (Agreement)	Rank
Cost-benefit analysis of sustainable practices	4.3913	4.6957	2.1866	Very high	1
Renewable energy integration	4.3043	4.6957	2.1918	Very high	2
BIM and sustainability integration	4.3043	4.6957	2.1918	Very high	2
Stakeholder engagement skills	4.2174	4.7391	2.2196	Very high	4
Sustainable construction finance	4.1304	4.4783	2.0888	High	5
Life cycle costing and assessment	4.0870	4.6522	2.1821	High	6
Water efficiency strategies	4.0000	4.4348	2.0739	High	7
Carbon footprint reduction strategies	3.9130	4.5217	2.1245	High	8
Sustainable deconstruction and demolition	3.9130	4.3913	2.0564	High	9
Responsible construction practices	3.9130	4.2609	1.9884	High	10
Sustainability strategy development	3.8696	4.3478	2.0363	High	11
Health and well-being considerations	3.8261	4.2609	1.9936	High	12
Lean principles	3.8261	4.2609	1.9936	High	13
Compliance with sustainable regulations	3.4783	3.8261	1.7876	High	14
Sustainable procurement expertise	3.3478	3.7826	1.7727	Moderate	15
Occupant behaviour analysis	3.3043	3.9130	1.8435	Moderate	16
Sustainable building certifications	3.1739	3.8261	1.8060	Moderate	17
Sustainable urban planning	2.9130	3.3913	1.5947	Moderate	18

A T-test was conducted to evaluate the significance of the gaps between the existing and expected sustainable construction competencies of quantity surveyors in Namibia. The test results, as shown in Table 4, revealed p-values of less than 0.05 for most competencies, indicating significant gaps between the current and expected competency levels in key areas such as Life cycle costing and assessment ($p = 0.0277$) and Carbon footprint reduction strategies ($p = 0.0255$). These findings suggest that there is a statistically significant gap for most competencies, highlighting the need for targeted training and upskilling in sustainable practices. However, four competencies, including Sustainable construction finance ($p = 0.0577$), Responsible construction practices ($p = 0.0835$), and Cost-benefit analysis of sustainable practices ($p = 0.0792$), showed p-values greater than 0.05, suggesting that the gap in these areas may not be as pronounced.

Table 4: Significant of gaps between existing and expected sustainable construction competencies

Sustainable construction competencies	T-Test P-value
Sustainable building certifications	0.0245
Carbon footprint reduction strategies	0.0255
Occupant behavior analysis	0.0265
Life cycle costing and assessment	0.0277
Stakeholder engagement skills	0.0289
Sustainable deconstruction and demolition	0.0303
Sustainability strategy development	0.0318
Sustainable urban planning	0.0335
Water efficiency strategies	0.0353
Health and well-being considerations	0.0374
Lean principles	0.0397
Sustainable procurement expertise	0.0424
Renewable energy integration	0.0454
BIM and sustainability integration	0.0489
Sustainable construction finance	0.0577
Responsible construction practices	0.0635
Compliance with sustainable regulations	0.0704
Cost-benefit analysis of sustainable practices	0.0792

Discussion

The results of this pilot study highlight notable gaps between the existing and expected sustainable construction competencies of quantity surveyors in Namibia. These findings align with the growing body of literature that emphasises the necessity of upskilling professionals in the construction industry to meet evolving sustainability demands (Olawumi & Chan, 2019; Ametepey & Aigbavboa, 2015)

Focusing first on the top five existing and expected competencies based on mean scores (Table 3), Cost-benefit analysis of sustainable practices had the highest mean score for both existing (4.39) and expected (4.70) competencies. This finding is consistent with studies by Howard (2015) and Ametepey & Aigbavboa (2015), which stress that cost-benefit analysis is central to convincing stakeholders to adopt sustainable practices, as it demonstrates the long-term financial benefits. This indicates that it is currently seen as a critical competency, but there remains room for improvement. Similarly, Renewable energy integration (mean score: 4.30 for existing, 4.70 for expected) and BIM and sustainability integration (4.30 existing, 4.70 expected) are competencies that have high importance but require further development. These results are consistent with the findings of Ma and Lui (2013), who emphasised the role of BIM in optimising resources and reducing waste in construction projects. However, the relatively small gap in BIM competency suggests that awareness of BIM exists in Namibia, though practical barriers such as limited access to technology or inadequate training may hinder widespread adoption. Other critical competencies identified include Stakeholder engagement skills (mean score: 4.21 existing, 4.74 expected) and Sustainable construction finance (4.13 existing, 4.40 expected), both of which are pivotal for aligning construction practices with sustainable goals. Stakeholder engagement plays a vital role in fostering collaboration among various construction stakeholders, a necessity for the successful implementation of sustainable strategies (Chandramohan et al., 2022). The need to improve these competencies reflects the growing importance of holistic, stakeholder-driven approaches in the construction sector.

Turning to the significant gaps between existing and expected competencies, the T-test results (Table 4) reveal that several competencies exhibit statistically significant differences ($p < 0.05$). Among these, Sustainable building certifications ($p = 0.0245$), Carbon footprint reduction strategies ($p = 0.0255$), and Occupant behaviour analysis ($p = 0.0265$) showed the most pronounced gaps. These findings align with previous research by Omotayo et al. (2023), which highlights the role of certifications like LEED (Leadership in Energy and Environmental Design) in promoting sustainable construction practices globally. This finding diverges from research in more developed contexts, where the integration of carbon footprint assessment tools is becoming more common (Olawumi et al., 2018). The disparity underscores the need for more targeted education and training programs that focus on the environmental impact of construction activities. The significant gap in Carbon footprint reduction strategies further underscores the importance of reducing emissions, particularly as construction phases are responsible for a significant proportion of carbon output (Ogunmakinde et al., 2017). Life cycle costing and assessment ($p = 0.0277$) also emerged as a critical area with a significant gap, reinforcing the conclusions of Jelgava (2018) and Tafazzoli (2018), who argue that proficiency in life cycle costing (LCC) is essential for ensuring the long-term financial viability and sustainability of construction projects. The current underutilisation of LCC in Namibia suggests a need for targeted training programs to address this gap, enabling quantity surveyors to better support clients in making cost-saving, sustainable decisions. Additional competencies such as Water efficiency strategies ($p = 0.0353$) and Sustainability strategy development ($p = 0.0318$) also displayed significant gaps, emphasising the need for the construction sector to adopt more comprehensive sustainability measures. As highlighted by Gunarathne et al. (2022), the development of integrated sustainability strategies, including certifications and resource-efficient practices, is essential for aligning Namibia's construction industry with international standards. On the other hand, Sustainable construction finance ($p = 0.0577$), Responsible construction practices ($p = 0.0835$), Compliance with sustainable regulations ($p = 0.0704$), and Cost-benefit analysis of sustainable practices ($p = 0.0792$) did not exhibit statistically significant gaps ($p > 0.05$). This indicates that, while these competencies remain important, the gap between current and expected levels is not as pronounced. These findings suggest that quantity surveyors in Namibia may already possess relatively sufficient capabilities in these areas, with less urgency for development compared to other competencies. Nevertheless, continuous improvement in these areas is still essential to meet future sustainability challenges, as supported by previous research (Howard, 2015; Ametepey & Aigbavboa, 2015).

Overall, the findings of this pilot study align with the broader literature on sustainable construction competencies, reaffirming the necessity of continuous education and professional development to close the gaps between current and expected competencies. The significant gaps in key areas such as Carbon footprint reduction strategies, Life cycle costing, and Sustainable building certifications highlight critical weaknesses in the current skill set of Namibian quantity surveyors, which must be addressed to ensure the long-term sustainability of the construction sector. In summary, the findings of this pilot study confirm that significant gaps exist between the current competencies of quantity surveyors and the skills required to drive sustainable construction in Namibia. Addressing these gaps will require a concerted effort from industry stakeholders, including enhanced training, policy reforms, and the integration of sustainability into professional development programs. These findings are in line with the broader literature on sustainable construction competencies, reinforcing the need for continuous education and policy support to build a more sustainable future for the Namibian construction sector.

Conclusion

This pilot study sought to determine the gap between the current and expected sustainable construction competencies among Namibian quantity surveyors. The findings reveal substantial discrepancies between existing competencies and the expected levels of proficiency, particularly in the top five areas: Cost-benefit analysis of sustainable practices, Renewable energy integration, BIM and sustainability integration, Stakeholder engagement skills, and Sustainable construction finance, all of which had high mean scores but still showed a need for improvement. Additionally, significant gaps were identified in competencies such as Sustainable building certifications, Carbon footprint reduction strategies, Occupant behaviour analysis, and Life cycle costing and assessment, with p-values less than 0.05 indicating statistically significant differences. These results underscore the critical need for enhanced training and tailored educational programs that equip quantity surveyors with the competencies necessary to promote sustainability in the construction industry. The limited application of these competencies in practice highlights the importance of formal education, professional development, and supportive policies. Addressing these gaps will not only enhance project outcomes but also enable Namibia's construction sector to align with international sustainability standards, ultimately contributing to the country's long-term environmental and economic goals.

While this pilot study provides useful insights, additional research with a larger sample size is underway to validate these findings and provide more comprehensive solutions for advancing sustainable construction competencies in Namibia. By closing the gap between current and expected competencies, Namibia's construction sector can improve its ability to deliver environmentally, socially, and economically sustainable projects.

Recommendations

- To address the gap in sustainable construction competencies among Namibian quantity surveyors, specialised training programs focused on sustainable construction competencies should be offered by the INQS and CIF in collaboration, with government offering financial incentives to support these programs.
- Quantity surveying curricula should also be updated to include sustainability principles, with practical experience provided through internships. Continuous professional development (CPD) should also keep professionals up to date with emerging technologies like BIM and renewable energy.
- Collaboration between government, academia, and industry is essential. A task force should be formed to identify barriers and promote sustainable construction through regular knowledge sharing and strategy development.
- Pilot sustainable construction projects will be essential for showcasing the feasibility and benefits of sustainable practices. The government, municipalities, and construction firms should fund these projects, with support from international. These projects will serve as case studies and learning opportunities, encouraging the wider adoption of sustainable practices.

By taking these specific and actionable steps, Namibia's construction industry can significantly enhance the sustainable competencies of its quantity surveyors, aligning with international standards and addressing the current gaps in professional skills. Partnership between government, academia, and

industry will be critical in ensuring that these recommendations are effectively implemented, ultimately driving Namibia toward a more sustainable future in the construction industry.

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Evaluating the Effects of Health and Safety Strategies on Social Sustainability in the Namibian Construction Industry

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Abstract

This research paper aims to evaluate the effects of health and safety (H&S) strategies on social sustainability on construction sites in Namibia. Social sustainability has currently received little attention in the construction industry despite its importance as one of the dimensions of sustainable development. A self-administered questionnaire survey was employed to gather data from Small and Medium-sized Contractors (SMCs), professional architects and quantity surveyors. The data was analysed by computing mean scores (MSs) and their ranking. The mean scores of a 5-point Likert scale were interpreted as MSs > 1.00 ≤ 1.79 (Very low impact), MSs > 1.80 ≤ 2.59 (Low impact), MSs > 2.60 ≤ 3.39 (Moderate), MSs > 3.40 ≤ 4.19 (High impact) and MSs > 4.20 ≤ 5.00 (Very high impact). The results of the study found that the H&S strategies implemented by most SMCs in Namibia highly influence most dimensions of social sustainability, such as improved company image, increased competitive advantage, improved employee satisfaction, improved employee/worker's health, improved gender equality, cost savings and increased productivity, as evidenced by mean scores within the point range of MSs > 3.40 ≤ 4.19 (high impact) and MSs > 4.20 ≤ 5.00 (very high impact). Even though the sample size and the mono-method quantitative approach adopted for the study provide valuable insights, they preclude the findings from being generalised without caution. The study results assist the construction stakeholders in strengthening the implementation of the identified H&S strategies to enhance social sustainability within the construction industry. There are limited studies evaluating the effects of H&S strategies on social sustainability within the Namibian construction industry. The findings could be utilised by key stakeholders in the construction industry to promote social sustainability, which is critical to employees' well-being.

Keywords: Health and Safety Strategies, Social Sustainability, Construction Workers, Employees' Wellbeing, Construction Industry.

Introduction

The construction industry is instrumental in advancing sustainable development agenda globally (Almahmoud & Doloi, 2014; 2020). Almahmoud and Doloi (2014) view sustainable development as focusing on the improvement of the quality of human life. To achieve sustainable development, three sustainability dimensions: economic, environmental, and social, ought to be balanced (Kordi, Belayutham & Che Ibrahim, 2021; Yilmaz et al., 2020; Zhang & Lu, 2018). While research confirms that economic and environmental dimensions have largely been emphasised over the years in the construction industry (Park, Yoon & Kim, 2017; Raslanas et al., 2013), the social dimension is arguably overlooked on construction projects in most developing countries (Taherkhani, 2023; Almahmoud & Doloi, 2020). Atanda (2019) argues that the assessment of social sustainability on construction projects is still nascent. However, considering the increased interest among stakeholders regarding social equalities, improved quality of life and sustainability of communities, a plethora of studies presently advocate for the prioritisation of social sustainability on construction projects (Santos et al., 2019; Eizenberg & Jabareen, 2017; Missimer et al., 2017).

Ideally, construction projects are undertaken to create job opportunities, generate wealth, redress inequalities, alleviate poverty, and enhance the quality of human life, particularly to the marginalised (Dhliwayo, Musonda & Gumbo, 2022; Bikitsha and Amoah, 2022). Additionally, the health and physical comfort of stakeholders is one of the parameters of social sustainability (Almahmoud & Doloi, 2020, Karakhan, 2020). Regrettably, most developing countries grapple with H&S concerns on construction sites, particularly among small and medium-sized contractors (SMCs) (Dhliwayo, Musonda, Gumbo & Kaisara, 2024). Hence, the question on how this affects social sustainability ensues. Clearly, most construction sites worldwide are susceptible to health hazards for workers and third parties which threaten the wellbeing of the victims. For instance, in Malaysia, Idris (2017) posits that the construction sector witnesses higher accident risk compared to other sectors. Similarly, in Iran, Soltanzadeh et al. (2016) note that the construction industry exhibits high risk of occupational accidents and bodily injuries. According to Chim, Chun and Wah (2018), these accidents are caused by multifarious factors which include uncertain operation procedures, poor design or selection, failure to enforce H&S measures, inadequate workmen training, inadequate coordination and communication, negligence of contractor and act of God. When these accidents occur, Chim, Chun and Wah (2018) contend that fatal injuries and or death of employees, projects delays, cost overruns and damaged company reputation, are possible consequences. Within the context of Malaysia, Idris (2017) suggests three strategies to mitigate accidents on construction sites in a bid to improve social sustainability. These measures as outlined by Idris (2017) include enforcement of H&S measures, establishment of an H&S management system and complying with the Occupational Safety and Health Act 1994 (OSHA, 1994).

Admittedly, most governments have over many years encouraged contractors within their jurisdictions to develop and implement H&S practices on construction sites (Adow, 2013; Shariff, 2011). However, the impact of such H&S management practices on social sustainability has remained underexplored in most developing countries (Taherkhani, 2023; Kordi, Belayutham & Che Ibrahim, 2021; Almahmoud & Doloi, 2020). With Namibia being one of the smallest populated developing countries within Southern Africa which is characterised by a paucity of literature related to its context, the current study evaluates the effect of H&S management strategies being implemented in Namibia on social sustainability in the construction industry. The study addresses two questions which include, (1) What are the H&S management strategies being implemented on construction sites in Namibia? and (2) What is the effect of H&S management strategies implemented in Namibia on social sustainability in the construction industry? The findings of this study could assist the construction stakeholders in Namibia and similar contexts to identify and implement H&S management strategies that promote social sustainability within the construction industry. Therefore, the succeeding sections start by reviewing literature related to the concept of social sustainability, health and safety management strategies in the construction industry, and effect of health and safety management strategies on social sustainability in the construction, then followed by the methodological approach employed, research results, discussion, conclusion, and recommendations.

Literature Review

The concept of social sustainability

Social sustainability is one of the three pillars of sustainable development concept (Kordi, Belayutham & Che Ibrahim, 2021; Yilmaz et al., 2020; Zhang & Lu, 2018). Yilmaz et al. (2020) view social sustainability as a set of practices that improve the welfare of people over the course of an activity's life cycle while considering the demands of both present and future partners. On the other hand, Littig and Griessler (2005) describe social sustainability from three dimensions namely equal opportunity, social cohesion and satisfaction of basic needs, while Bramley et al. (2009) view social sustainability from two-dimensional perspective which include social equality and sustainability of communities. Almahmoud and Doloi (2020) enunciate that social equality dimension entails equal opportunity for employment and accessibility to services, while sustainability of communities encompasses social interaction, social cohesion and social capital. Despite the dimension through which one views social sustainability concept, Valdes-Vasquez and Klotz (2013) claim that the process of attaining social sustainability largely includes stakeholder engagement, user considerations, team formation, management considerations, impact assessment and place context. In the past, emphasis has been put on economic and environmental sustainability, while underrating the social pillar (Kordi, Belayutham & Che Ibrahim, 2021). However, Kordi, Belayutham and Che Ibrahim (2021) note that neglecting one of the sustainable pillars such as social sustainability during the construction process could culminate

in poor security and health. This is corroborated by Zuo *et al.* (2012) who affirm that compromising on social sustainability has a deleterious impact on equity, security, health and access to basic needs. Hence, the incorporation of social sustainability into the construction projects has been increasing in the recent years, as alluded to by Wang, Zhang and Lu (2018). It is therefore rational to underscore that there is no sustainable development without considering the social sustainability dimension. Thus, it is imperative to balance social aspects on the sustainability equation. The measurements of social sustainability have however been noted as subjective due to their qualitative nature such as people's opinions, perceptions and satisfaction (Taherkhani, 2023; Almahmoud & Doloi, 2020).

Health and safety management strategies in the construction industry

It is imperative that Health and Safety (H&S) practices be complied with on any construction site for the wellbeing of employees and third parties (Eze, Sofolahan & Siunoje, 2020; Aghimien, Aigbavboa & Thwala, 2019). Considering the vulnerability of most construction sites in developing countries, there has been a clarion call for key stakeholders in these countries to develop comprehensive H&S programmes to combat occupational diseases and accidents (Yiu, Chan, Shan & Sze, 2019). As argued by Adow (2013), implementing H&S programmes on construction sites has traditionally been one of the most effective strategies to ameliorate construction accidents.

Hinze *et al.* (2013) point out that, even though there are existing H&S rules promulgated by several governments to cover workers' H&S, these rules do not sufficiently address the management of H&S on most construction sites. The development and implementation of H&S plans, good worker welfare, and government and client support are the main factors that entrench H&S management practices, particularly among small and medium-sized contractors (SMCs) (Eze, Sofolahan & Siunoje, 2020; Aghimien, Aigbavboa & Thwala, 2019).

It should be noted that H&S is a global concern (Shariff, Leong & Zaini, 2012). This is evidenced by the prevalence of several international protocols or standards that govern H&S globally, such as BS8800 - 2004 Guide to Occupational Health and Safety Management Systems, HS(G)65 - Successful Health and Safety Management, BS OS 18001 - Occupational Health and Safety Management, and ISO 45001- Occupational health and safety management (Yiu *et al.*, 2019). A plethora of studies confirm that the safety management could be successfully implemented by considering several factors which include (1) the overall management, which includes the occupational health and safety policy, goals, and objectives, (2) project planning, which includes the planning and development, (3) project operation, which includes the training, (4) hazard control, prevention and corrective action systems and (5) commitment from the management and allocation of resources (Chigara & Smallwood, 2019; Chim, Chun & Wah, 2018; Idris, 2017). Chigara and Smallwood (2019) further highlight that the long-term health and safety management can be enhanced by directing and overseeing the application of H&S components and enforcing H&S regulations, dissemination of H&S information, compensation, and post-injury return to work plans. However, Shariff, Leong and Zaini (2012) put emphasis on the comprehensiveness of the H&S policy, arguing that a complete policy should comply not only with national and international regulations, but also foster improving the overall business performance of the company for effective H&S management. Impliedly, the H&S policy ought to be unique or adaptive to the company's needs to guarantee a safe and healthy workplace.

Effect of health and safety management strategies on social sustainability in the construction industry

Health and safety management plays a significant role in improving employees' quality of life (Vitharana *et al.*, 2015). This is corroborated by Karakhan (2020) who views H&S as a primary indicator of social sustainability. The adoption of good H&S practices demonstrates the company's dedication to employees' welfare. Hassana *et al.* (2013) note that, taking an active personal role in H&S leads to improved wellbeing of workers. On the other hand, Lee and Quinn (2020) posit that the organisation's H&S culture can influence employees' behaviour or attitude towards risk reduction. This is corroborated by Yiu *et al.* (2019) who opine that the H&S management system components have potential to minimise absenteeism and turnover of staff, reduce accidents related costs, boost staff morale and increase productivity. As argued by Buniya *et al.* (2021), H&S programmes are implemented on construction projects for numerous reasons which include avoiding unnecessary and dangerous conducts, reporting risks and hazards, ensuring that accidents are documented and handled appropriately. Buniya *et al.* (2021) claim that organisations that have implemented H&S programmes

enhanced the quality of their work, increased their reputation, improved collaboration among staff and increased their profits. Therefore, the implementation of H&S management practices is expected to yield a positive effect on social sustainability. However, as previously noted, the performance of most of the H&S programmes in promoting social sustainability in the construction industries of most developing countries has continued to be weak.

Research Methodology and Method

The study employed a quantitative approach to gather data from registered professional quantity surveyors and architects, as well as construction sites of small and medium-sized Contractors (SMCs), using a self-administered questionnaire survey tool. As pointed out by several scholars (Leavy, 2017; Saunder, Lewis & Thornhill, 2016), a quantitative approach assisted in objective evaluation of the data and generalisability of the results. Thus, the study adopted the approach to investigate the H&S management strategies used to enhance social sustainability on construction projects in Namibia and to assess the effect of H&S management strategies on social sustainability on construction projects in Namibia. The study was delimited to Windhoek since it is the capital city, as well as both the commercial and administrative centre of Namibia where most quantity surveyors, architects and SMCs are headquartered. Quantity surveying and architectural professionals were drawn from the list of the Namibian Council of Architects and Quantity Surveyors (NCAQS), while construction sites of small and medium-sized contractors were selected using convenient and snowball sampling. As confirmed by Offei, Kissi and Nani (2019), snowballing is most appropriate when confronted with difficulties in identifying respondents who are acquainted with the phenomenon. The target population for the study comprised thirty construction sites (30) of SMCs, thirty-seven (37) registered quantity surveying firms and eighty-six (86) architectural firms. A census was employed, thereby distributing the questionnaire to all the targeted respondents. A web-based questionnaire was then emailed to the principals of quantity surveying firms and architectural firms, while hardcopy questionnaires were physically administered to one of the health and safety representatives of SMCs on the identified construction sites. The administered questionnaire had three sections, of which the first section considered the respondents' demographic variables such as profession, educational level and work experience. The second section sought to probe the insights of respondents on the H&S management strategies used by SMCs on construction projects in Namibia, while the third section asked respondents on the effect of H&S management strategies on social sustainability on construction projects in Namibia. Respondents were asked to rate the frequency of usage of each of the shortlisted strategies in managing H&S on construction sites in Namibia, and the effect of such H&S management strategies on social sustainability on construction sites, using a five-point Likert scale. Data was analysed using mean scores. Mean interpretation range for the first objective was as follows: Not frequent in the point range of $MSs > 1.00 \leq 1.79$, Less frequent $MSs > 1.80 \leq 2.59$, Neutral $MSs > 2.60 \leq 3.39$, Frequent $MSs > 3.40 \leq 4.19$ and Most frequent $MSs > 4.20 \leq 5.00$, while for the second objective was as follows: Very low impact in the point range of $MSs > 1.00 \leq 1.79$, Low impact $MSs > 1.80 \leq 2.59$, Moderate $MSs > 2.60 \leq 3.39$, High impact $MSs > 3.40 \leq 4.19$ and, Very high impact $MSs > 4.20 \leq 5.00$.

Research Results

Response rate

Questionnaires were distributed to registered quantity surveyors and architects, as well as health and safety representatives on construction sites of SMCs which are based in Windhoek. A total of 153 questionnaires were distributed, with 30 being administered as hard copies, while the remaining 123 were administered online via Google Forms for easy accessibility to the targeted respondents. A response rate of 48% was attained. The response rate aligns with findings from a previous study by Moser and Kalton (1979) who argue that survey results could be biased and of limited value if the response rate is below 30%-40%. However, Sauro and Lewis (2016) contend that the analysis of 21 to 28 respondents could give valid results. Therefore, the response rate can be deemed acceptable.

Table 1: Response rate

Data collection tools	Target population	Responses archived	Respondents rate (%)
Questionnaires for SMCs	30	19	63
Questionnaires for QS firms	37	22	59
Questionnaires for Architectural firms	86	32	37
TOTAL	153	73	48

Demographic information of respondents

Table 2 shows the demographic information of the respondents related to the designation, work experience and educational qualifications.

Table 2: Demographic information of respondents

Demographic	Frequency	Percentage
Designation		
H&S Officer	6	8
Site Manager	4	6
Foreman	9	12
Quantity Surveyor	22	30
Architect	32	44
Total	73	100
Work experience		
1 - 5 years	7	9
6 - 10 years	32	44
11 - 15 years	14	19
15+ years	20	28
Total	73	100
Educational qualification		
National certificate	0	0
Diploma	34	47
Bachelor's Degree	12	16
Honour's Degree	20	28
Master's Degree	7	9
Total	73	100

Table 2 indicates that the respondents comprised H&S officers (8%), site managers (6%), foremen (12%), quantity surveyors (30%), and architects (44%). This composition provided diversified insights regarding the health and safety strategies being implemented in Namibia, including the effect of such strategies on social sustainability in the Namibian construction industry.

Regarding work experience, most of the respondents had work experience ranging between 6 to 10 years (44%), followed by those with work experience above 15 years (28%), while 19% had between 11 to 15 years' experience. Comparatively, consultants were more experienced than representatives of SMCs. In addition, most of the respondents were holders of diplomas (47%), followed by 28% with honour's degrees, while 16% possessed bachelor's degrees, with a few having master's degrees (9%).

Health and safety management strategies implemented on construction projects in Namibia

The study required respondents to indicate how H&S management is being implemented on construction sites in Namibia, based on criteria which included health and safety company policy, health and safety planning, health and safety practice, health and safety monitoring and control. Questions were posed on each criterion, of which respondents were asked to rate the compliance or implementation level on construction sites using a 5-point Likert Scale, with 1 representing not at all, 2 – less frequent, 3 – frequent, 4 – more frequent and 5 – most frequent. The data analysis entailed the computation of mean scores. Table 3 shows the results of the study.

Table 3: Health and safety management strategies on construction sites in Namibia

H&S Management Strategy	N	Mean Score	Rank
H&S Company Policy			
Formulation and review of H&S policy.	73	3.88	1
Conducting initial reviews of the company's existing arrangements for managing H&S.	73	3.81	2
Does the company regularly prepare and write a policy and programme on the protection of the H&S of its employees	73	3.66	3
Health and Safety planning			
Does your company make a thorough plan to implement the workplace H&S policy?	73	3.65	1
Does your company put its strategies into action with commitment, documentation, expertise, training, and awareness to achieve the strategy?	73	3.53	2
Does your company base its planning on several judgments on the size, structure, and frequency of audit strategy, as well as the effectiveness of the system?	73	3.31	3
Health and Safety practice			
Does the company provide PPE to employees?	73	4.72	1
Does the company provide necessary information, instructions, training and supervision on H&S matters?	73	4.44	2
Do H&S representative regularly inspect construction site.	73	4.06	3
Do workers immediately notify their employer or a H&S representative of any hazardous or unhealthy conditions?	73	3.84	4
Do employees use the recommended safety equipment or wear the recommended safety clothes as necessary?	73	3.81	5
Health and Safety monitoring and control			
Incident reporting and keeping track of the location where work is done.	73	4.34	1
Keeping relevant records of H&S action taken to meet legal requirements periodically, as well as auditing.	73	4.19	2
Making use of outcomes of workplace H&S inspection to enhance the system, programme, and policy for H&S.	73	4.09	3
Auditing the company's H&S programme, system, and policy on a regular basis.	73	3.50	4
Valid N (listwise)	73		

The mean scores on Table 3 were interpreted as follows: **Not frequent** in the point range of MSs >1.00 ≤ 1.79, **Less frequent** MSs >1.80 ≤ 2.59, **Neutral** MSs >2.60 ≤ 3.39, **Frequent** MSs >3.40 ≤ 4.19 and **Most frequent** MSs >4.20 ≤ 5.00. Therefore, regarding H&S policy, the results show that most SMCs frequently formulate and review their H&S policy, conduct initial reviews of the company's existing arrangements for managing H&S, and regularly prepare a company policy and programme to protect the H&S of their company's employees, as indicated by the mean scores within the point range of MSs >3.40 ≤ 4.19.

Moreover, regarding H&S planning, most respondents believed SMCs frequently make a thorough plan to implement the workplace H&S policy, as well as putting its strategies into action with commitment, documentation, expertise, training, and awareness to achieve the strategy, as the mean score for the

questions related to the two aspects fall within the point range of $MSs > 3.40 \leq 4.19$. However, majority of respondents appeared sceptical regarding whether the SMC company base its planning on several judgments which include the size, structure, and frequency of audit strategy, as well as the effectiveness of the system, as indicated by mean scores within the point range of $MSs > 2.60 \leq 3.39$. Thus, most respondents were undecided as to whether SMCs follow a meticulous process during H&S planning.

Pertaining to H&S practice, the data analysis shows that most respondents perceived that SMCs most frequently exercise H&S practices such as provision of PPE to employees and necessary information, instructions, training and supervision on H&S matters, as indicated by mean scores within the point range of $MSs > 4.20 \leq 5.00$. Also, most respondents opined that SMCs frequently conduct regular inspections of construction sites for H&S compliances and that workers frequently notify their employers about any hazardous or unhealth conditions, as well as frequently putting on their recommended safety gear, as indicated by mean scores within the point range of $MSs > 3.40 \leq 4.19$. Similarly, majority of respondents believed that SMCs highly conduct H&S monitoring and controlling mechanisms through frequent incident reporting and keeping track of the location where work is done, as indicated by a mean score within $MSs > 4.20 \leq 5.00$. Additionally, most respondents believed that SMCs frequently keep relevant records of H&S to meet legal requirements periodically, including regular audit of H&S issues, and making use of outcomes of workplace safety inspection to enhance the system, program, and H&S policy, as shown by mean scores within the point range of $MSs > 3.40 \leq 4.19$. Generally, the results show that SMCs have several H&S management strategies that they frequently implement on construction sites.

Effect of health and safety management strategies on social sustainability on construction sites in Namibia

The study examined the H&S management strategies on social sustainability on the Namibian construction sites. The respondents were asked to rate the extent to which H&S strategies impacted the identified social sustainability principles using a 5-point Likert scale, where 1 represents Very low impact, 2 – Low impact, 3 – Moderate, 4 – High impact and 5 – Very high impact. Table 4 shows that results of the study.

Table 4: Effect of health and safety management strategies

Effect	N	Mean Score	Rank
Improved company image	73	4.41	1
Increased competitive advantage	73	4.22	1
Improved employee satisfaction	73	4.19	1
Improved employee/worker's health	73	4.19	4
Increased productivity	73	4.13	4
Better insurance terms	73	4.09	6
Improved management and leadership	73	4.03	7
Cost savings	73	3.94	8
Less safety incidents	73	3.91	9
Increased cooperation between different stakeholders	73	3.72	10
Improved gender equality	73	3.69	10
Less employment cost	73	3.63	10
Created a more harmonious society	73	3.59	13
Less industry-relational complaints	73	3.56	14
A small number of complaints from neighbourhood communities during construction	73	3.38	15
Valid N (listwise)	73		

The means on Table 4 were interpreted as follows: Very low impact in the point range of $MSs > 1.00 \leq 1.79$, Low impact $MSs > 1.80 \leq 2.59$, Moderate $MSs > 2.60 \leq 3.39$, High impact $MSs > 3.40 \leq 4.19$ and, Very high impact $MSs > 4.20 \leq 5.00$. From Table 4, the results show that H&S strategies implemented by SMCs in Namibia exhibited a very high impact on two of the fifteen indicators of social sustainability which include improved company image and increased competitive advantage, whose mean scores are within the point range of $MSs > 4.20 \leq 5.00$. Additionally, majority of respondents believed that H&S strategies employed by SMCs highly impact all the identified parameters of social sustainability which include improved employee satisfaction, improved employee/worker's health, increased productivity,

better insurance terms, and improved management and leadership, as indicated by mean scores within the point range of $MSs > 3.40 \leq 4.19$. In a nutshell, the results confirm that H&S strategies utilised by SMCs in Namibia highly impact social sustainability on construction sites.

Discussion

The findings show that most SMCs in Namibia have got comprehensive H&S policies, and fairly conduct thorough H&S planning. Moreover, the study found that most of the SMCs implement H&S practices, and H&S monitoring and controlling mechanisms on construction sites to cater for the wellbeing of workers on site. The findings align with Yiu, Chan, Shan and Sze (2019) who suggest the need for comprehensive H&S programmes to combat diseases and fatalities on construction sites. Similarly, Leong and Zaini (2012) put emphasis on the comprehensiveness of the H&S policy, arguing that a complete policy should comply not only with national and international regulations, but also foster improving the overall business performance of the company for effective H&S management. Evidently, several countries like Malaysia (Idris, 2017) and Iran (Soltanzadeh *et al.*, 2016) have encouraged contractors to implement H&S practices on sites. A plethora of studies highlight that the measures which contribute to the comprehensiveness of the H&S programme include: (1) H&S policy, goals, and objectives, (2) project planning, which includes the planning and development, (3) project operation, which includes the training, (4) hazard control, prevention and corrective action systems and (5) commitment from the management and allocation of resources (Chigara & Smallwood, 2019; Chim, Chun & Wah, 2018; Idris, 2017). However, although comprehensive H&S policies have been reportedly implemented in countries like Malaysia (Idris, 2017) and Iran (Soltanzadeh *et al.*, 2016), these authors found that H&S management guidelines are inadequately complied with, thereby raising the question of how H&S management strategies being implemented impact the social sustainability in such contexts.

Following a probe on the perception of various respondents regarding the effect of H&S management strategies on social sustainability on construction sites in Namibia, the results show that the strategies being implemented have high ($MSs > 3.40 \leq 4.19$) to very high ($MSs > 4.20 \leq 5.00$) impact on all the identified parameters of social sustainability which include improved company image, increased competitive advantage, improved employee satisfaction, improved employee / worker's health, increased productivity, better insurance terms and improved management and leadership, cost savings, less safety incidents, increased cooperation between different stakeholders, improved gender equality, less employment cost, creation of a more harmonious society, less industry-relational complaints and a small number of complaints from neighbourhood communities during construction. These findings align with several studies (Buniya *et al.*, 2021; Karakhan, 2020; Lee & Quinn, 2020; Vitharana *et al.*, 2015) which assert that H&S practices improve employees' quality of life. This was elaborated by Buniya *et al.* (2021) who claim that organisations that have implemented H&S programmes enhance the quality of their work, increase their reputation, improve collaboration among staff and increase their profits. Thus, H&S management strategies utilised by SMCs in Namibia contribute immensely to social sustainability within this context.

Conclusion

Social sustainability remains one of the three pillars of sustainability that has been neglected on construction sites for many years, despite its importance in improving the quality of lives of employees. The current study therefore sought to assess the H&S management strategies being implemented by SMCs in Namibia and evaluate their effect on the social sustainability within the Namibian construction industry. Based on the results, the study found that most SMCs in Namibia frequently ($MSs > 3.40 \leq 4.19$) or most frequently ($MSs > 4.20 \leq 5.00$) implement numerous H&S management strategies which include comprehensive H&S policies, good H&S practices, and H&S monitoring and control on their construction sites. These H&S management systems were also found to be having a high ($MSs > 3.40 \leq 4.19$) to very high ($MSs > 4.20 \leq 5.00$) impact on all the identified parameters of social sustainability which include cost savings, less safety incidents, increased cooperation between different stakeholders, improved gender equality, less employment cost, creation of a more harmonious society, less industry-relational complaints, reduced complaints from neighbourhood communities during construction. Hence, the study concludes that the H&S management strategies implemented by SMCs in Namibia highly influence social sustainability on construction sites. As such, these H&S management strategies should be prioritised to enhance social equality and sustainability of the communities.

Therefore, the insights from the study could assist construction stakeholders to identify and implement H&S management strategies that would promote social sustainability within the construction industry in Namibia and similar contexts, particularly in the Global South. Consequently, employees' quality of lives could be promoted, while SMCs gain good reputation which could culminate in more job opportunities from satisfied clients.

Although the study provides invaluable insights, the small sample size used, geographical delimitation and the mono-method quantitative approach employed, preclude the findings from being generalised without caution.

Recommendations

Based on the results, the study recommends that stakeholders and SMCs in the Namibian construction industry adopt the identified H&S management strategies such as comprehensive H&S company policy, thorough H&S planning, good H&S practices and regular H&S monitoring and control, to enhance social sustainability. Considering the limitations of the study, future research can broaden the study to the whole of Namibia, using a large sample size comprising both SMCs and larger contracting firms, as well as enquiring using a mixed method approach. Additionally, further studies can employ advanced inferential statistical methods to verify the correlation between H&S management and social sustainability in the construction industry in developing countries.

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Evaluation of the Circular Construction Knowledge From Quantity Surveyor's Viewpoint

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Abstract

Within the construction industry, the transition to circular construction practices represents an event of significance aimed at reducing waste, increasing resource efficiency, and encouraging the design of buildings for longer lifespans, reuse, and recycling, thereby fostering a more sustainable built environment. This study investigates the role of quantity surveyors in implementing sustainable practices within the construction industry, with a specific focus on their competence and knowledge related to circular construction practices. Employing a qualitative research design, the study conducted semi-structured interviews with quantity surveyors to gather insights into their understanding and application of circular building concepts. The data was analysed thematically to identify trends and perceptions. Findings reveal a significant gap in quantity surveyors' awareness and utilisation of circular building techniques. Despite recognising such practices' environmental and economic benefits, a lack of specific expertise limits their widespread adoption. The study is limited by its qualitative nature, which may not capture the quantitative aspects of knowledge gaps and implementation barriers. However, it provides foundational insights into quantity surveyors' educational and professional development needs. To address these gaps, the study advocates for targeted training programs and government initiatives to enhance quantity surveyors' expertise in circular construction methods. Enhancing their competencies is essential for promoting sustainable practices in the construction industry. The study underscores the pivotal role of quantity surveyors at the intersection of tradition and innovation in construction. By equipping them with the necessary skills to implement circular building practices, they can lead the sector towards a sustainable and economically viable future, aligning with the conference's theme of disrupting traditional professional methods.

Keywords: Circular Economy, Construction Industry, Sustainability, Waste Management.

Introduction

According to projections, the construction sector is expected to make up 15% of the worldwide Gross Domestic Product by 2020. Additionally, it is forecasted to see a 4% yearly increase in the coming years (Francis and Thomas, 2020). Construction is projected to be the industry with the highest rate of growth in the next ten years (Francis and Thomas, 2020). However, the effects of the building sector are varied. On one side, the industry greatly enhances the overall well-being of individuals by constructing buildings and infrastructure that meet the socio-economic requirements of individuals, communities, and countries. However, construction activities require a significant number of natural resources that are not renewable. This leads to environmental degradation due to pollution, harm to fragile ecosystems, and the emission of greenhouse gases, which pose a threat to the future (Nguyen et al., 2017; Goel et al., 2019). Similarly, the construction of infrastructure in mountainous regions results in the removal of forests, disposal of construction waste, detonation of rocks, and alteration of surface drainage systems. These activities contribute to landslides, floods, failures in earthworks, and other geological hazards (Bhandari, 2006; Hearn and Shakya, 2017). Remarkably, the industrial sector utilises more than 50% of the world's raw resources, 40% of its energy, 12% of its water, and releases nearly 40% of its greenhouse emissions (Goel et al., 2019; Murtagh et al., 2020; Said and Berger, 2014). Therefore, sustainable and circular building techniques and practices have garnered significant attention from stakeholders. The aforementioned strategies to mitigate the environmental, economic, and social consequences arising from various stages of construction projects' life cycle (namely, conceptualisation, design, construction, use, and demolition) (Carvajal-Arango et al., 2019; Liu et al., 2022). Therefore, the adoption of sustainable and circular practices helps to reduce resource

consumption, promote the reuse of resources, enhance the utilisation of renewable or recyclable resources, safeguard the environment, establish a non-toxic and healthy ecosystem, and prioritise quality in the constructed environment (Ghisellini et al., 2016; Sangwa and Sangwan, 2023).

This study utilises an in-depth qualitative research technique to achieve its main goal which is to investigate and delineate the level of knowledge and comprehension that quantity surveyors possess regarding circular building processes in the South African construction sector. The research aims to provide insights into the distinct problems and opportunities associated with the implementation of sustainable construction technologies in South Africa. The qualitative approach was chosen due to its capacity to offer in-depth and detailed comprehension of the perspectives, experiences, and knowledge of quantity surveyors. These professionals play a crucial role in promoting the use of sustainable practices in construction projects through their expertise in cost management and project planning.

Literature Review

Circular construction principles and their relevance to sustainable development

The concepts of circular construction are based on the overarching idea of the circular economy, which seeks to separate economic progress from the use of resources and the deterioration of the environment. Ossio, et al., (2023) stipulate that ideas included in this approach are the deliberate design for long-term use, the encouragement of efficient use of resources, the facilitation of material reuse and recycling, and the generation of value from waste. MacArthur (2017) asserts that circular construction within the construction industry encompasses various strategies including modular construction, utilisation of sustainable and recyclable materials, designing buildings and infrastructure for disassembly, and implementing building information modeling (BIM) to optimise the efficiency and sustainability of construction projects. Circular building aims to reduce waste and resource consumption while promoting the restoration and regeneration of materials, resulting in a more resilient and adaptive built environment (Lacy and Rutqvist 2015). This method starkly contrasts with the conventional linear paradigm of 'take, make, discard,' providing a route to more sustainable building techniques that have the potential to substantially decrease the environmental impact of the industry (MacArthur 2017).

The significance of circular building concepts in sustainable development is substantial since they tackle crucial environmental issues such as waste creation, resource depletion, and greenhouse gas emissions (Ossio, et al., 2023). By incorporating sustainability throughout the entire lifespan of construction projects, these principles help to fulfil various United Nations Sustainable Development Goals (SDGs), such as promoting responsible consumption and production (SDG 12), creating sustainable cities and communities (SDG 11), and acting against climate change (SDG 13) (Easterly, 2015). Moreover, the use of circular building methods not only reduces environmental effects, fosters innovation, generates new business prospects, and strengthens economic resilience (Akanbi et al., 2019). Implementing circular principles may result in cost savings by minimising material consumption and waste and promoting the development of a market for recycled materials and environmentally friendly technology (Korhonen et al., 2018). Hence, circular construction is not only a tactic for ecological sustainability; it embodies a comprehensive methodology that incorporates economic, social, and environmental aspects, emphasising its crucial function in promoting sustainable development in the construction sector and beyond. The role of quantity surveyors in construction projects, with a focus on sustainability and circular economy practices.

Victar, et al., (2024) states that quantity surveyors are essential in building projects since they are responsible for managing and overseeing the financial and technical aspects of construction expenses and contracts. Their duties include cost estimation, overseeing contracts, and predicting financial outcomes, ensuring that projects are finished within the allocated budget and by stated criteria (Siriwardhana, et al., 2024). Quantity surveyors have increasingly taken on the responsibility of incorporating sustainability and circular economy techniques into the building sector. This change is a result of the increasing acknowledgment of the building industry's substantial influence on the environment, including the depletion of resources and the development of trash (Victar, et al., 2024). Quantity surveyors have a distinct advantage in their ability to shape sustainable building practices by being involved in the first phases of project planning and throughout the construction process (Siriwardhana, et al., 2024). By incorporating the concepts of the circular economy, such as minimising waste, maximising resource efficiency, and utilising sustainable materials, quantity surveyors can encourage the implementation of methods that decrease environmental effects and enhance the durability and recyclability of construction projects (Khalfan, 2006; Gould and Sauther, 2006).

To integrate sustainability and circular economy ideas into the field of quantity surveying, one must possess a profound comprehension of sustainable materials, lifetime costing, and the environmental ramifications of building processes (Karaca, et al., 2024). Quantity surveyors use this expertise to promote sustainable design decisions, assess materials' enduring worth and effectiveness, and execute plans for conserving resources and minimising waste (Victar, et al., 2024). They play a crucial role in carrying out sustainability evaluations, such as BREEAM or LEED certifications, that guide the sustainable development of building projects. Furthermore, via the use of techniques such as Building Information Modelling (BIM), quantity surveyors may improve the accuracy of cost estimates and material specifications, encouraging the effective utilisation of resources and simplifying the process of reusing or recycling materials at the end of their lifespan (Siriwardhana, et al., 2024). The adoption of a comprehensive and sustainable strategy not only supports worldwide environmental objectives but also provides economic advantages, including reduced expenses and enhanced project worth (Karaca, et al., 2024). This emphasises the crucial contribution of quantity surveyors in promoting sustainability and circular economy practices in the construction sector (Akanbi et al., 2019; Ojo et al., 2019).

Challenges and opportunities in implementing circular construction

In many instances, existing legal and regulatory frameworks have not evolved to support circular construction practices. The construction sector often grapples with regulatory policies that are either outdated or not in alignment with the principles of the circular economy, making it difficult for professionals and companies to adopt sustainable practices (McManners, 2023). Such legal frameworks may not only fail to encourage recycling and reuse of materials but may also inadvertently penalise innovative circular practices due to rigid compliance requirements. Moreover, another challenge encountered is the initial cost of implementing circular construction practices can be prohibitive, especially in a price-sensitive market like South Africa. The upfront investment in sustainable materials and construction techniques often dissuades stakeholders, particularly in a context where the economic benefits of circular practices, such as long-term savings and resource efficiencies, are not immediately apparent (Jacobs et al., 2022).

There is a significant knowledge gap among construction professionals, including quantity surveyors, regarding circular construction. The lack of comprehensive educational programs and training that embed circular economy principles into the curriculum limits the industry's capacity to adopt such practices (Adekunle et al., 2023). Without a deep understanding of circular construction benefits and techniques, professionals may be reluctant to deviate from traditional methods. This is due to the construction industry traditionally being conservative, and there may be cultural resistance to adopting new practices. This is compounded by a lack of awareness and understanding of the environmental impact of construction activities. Changing these attitudes requires a cultural shift that values sustainability and long-term environmental stewardship over short-term gains (Benachio et al., 2020).

Nevertheless, things like advances in technology offer significant opportunities for circular construction. For example, the use of Building Information Modelling (BIM) can enhance the efficiency of resource use and facilitate the reuse and recycling of materials. Additionally, new materials and construction methods that support circularity are continually being developed, presenting an opportunity to overcome some of the technical and material-related barriers to circular construction (Banihashemi et al., 2023). Moreover, developing educational programs and training that focus on circular economy principles can equip current and future professionals with the knowledge and skills required to implement circular construction practices. Universities, technical colleges, and professional associations play a critical role in fostering an understanding of sustainable construction practices (Skanska, 2021). This will increase public awareness of environmental issues and the global push towards sustainability are creating a cultural shift in many sectors, including construction. This growing environmental consciousness can serve as a catalyst for the adoption of circular construction practices, as both clients and contractors become more open to sustainable approaches (Liu et al., 2022).

Research Methodology and Method

The study adopted a qualitative research methodology utilising interviews as the study research design. This methodology is chosen for its strength in developing a theoretical framework based on empirical data, gathered directly from participants' experiences and viewpoints. The research employs semi-structured interviews as the primary data collection method, carefully designed to elicit detailed insights and personal reflections from a purposively selected group of quantity surveyors as outlined in Table 1.

These professionals are chosen based on their involvement in projects and academia, which demonstrate elements of circular construction, ensuring a rich diversity of knowledge and experiences. The interviews are meticulously transcribed, and the data is analysed using thematic analysis, allowing themes and patterns related to circular construction knowledge of circular construction.

This qualitative exploration is supported by an extensive review of existing literature, creating a comprehensive background that underpins the study's objectives and questions. The iterative process of data collection and analysis ensures that the emerging theory is grounded in the reality of the participants' experiences, providing a robust foundation for the study's conclusions. By focusing on the quantity surveyors' perspective, the research sheds light on the critical role these professionals play in facilitating the transition towards more sustainable, circular construction practices. It also identifies knowledge gaps, barriers to adoption, and opportunities for enhancing the integration of circular principles in construction projects. The study's qualitative methodology, combining grounded theory with thematic analysis, ensures a nuanced understanding of the complex interplay between knowledge, practice, and the potential for innovation in the field of circular construction.

A series of interviews were arranged with the participants. The purpose of these interviews was to get understanding of the participants' competence in the present levels of knowledge about circular construction. Aligned with the qualitative methodology, the particular technique used for gathering empirical data is semi-structured interviews with participants, since interviews continue to be a widely used form of data collecting in the field of construction (Haigh, 2008). The research used purposive sampling, thereby sending email invitations to 60 registered applicants and professionals located in Bloemfontein Free State, South Africa. The research included registered candidates with a minimum of 10 years of experience, and professionals with a minimum of 5 years of experience obtained after registration. A total of 14 individuals consented to take part in the investigation. The interviews were carried out in person. In the interviews, participants were asked to share their understanding, familiarity, and knowledge of circular construction.

Unique participants were coded as follows:

- JQS(n) = Junior QS from interview
- SQS(n) = Senior QS from interview
- LQS(n) = Lecturer from interview
- SLQS(n) = Senior Lecturer QS from interview.

Table 1: Interviewed Quantity Surveyors

Participant no	Sector	Participant code	Position	Professional Qualification
A	Private sector	JQS (1)	Junior Quantity Surveyor	C.QS
B	Public sector	JQS (2)	Junior Quantity Surveyor	C.QS
C	Public sector	SLQS (1)	Senior Quantity Surveyor and Lecturer	Pr.QS
D	Private sector	SQS (1)	Senior Quantity Surveyor	C.QS
E	Private sector	SQS (2)	Senior Quantity Surveyor	C.QS
F	Public and Private sector	SLQS (2)	Senior Quantity Surveyor and Lecturer	Pr.QS
G	Private sector	JQS (3)	Junior Quantity Surveyor	C.QS
H	Public sector	LQS (1)	Lecturer	Pr.QS
I	Public sector	LQS (2)	Lecturer	Pr.QS
J	Public sector	SQS (3)	Senior Quantity Surveyor	Pr.QS
K	Private sector	JQS (4)	Junior Quantity Surveyor	C.QS
L	Public sector	SQS (4)	Senior Quantity Surveyor	C.QS
M	Public and private sector	SLQS (3)	Senior Quantity Surveyor and Lecturer	Pr.QS
N	Private sector	JQS (5)	Junior Quantity Surveyor	C.QS

Note: C.QS = Candidate Quantity Surveyor
Pr.QS = Professional Quantity Surveyor

Research Results

Theme 1: Awareness and understanding of circular construction practices

All respondents were found to have a restricted understanding of circular building methods. Apart from one respondent, all respondents acknowledged that their first exposure to the concept of 'circular building' was via this research. Prior to participating in the interview, they had to engage in more reading on the subject to have sufficient confidence. Regarding this topic, the participants were queried about their comprehension of circular construction and to pinpoint any related procedures. During most of the interviews, the participants consistently offered identical responses to both questions, all of which focused on recycling and reusing building materials.

LQS(1) "...I think it is when you use either existing buildings or existing materials and re-use it within a new project. It is a cycle, not necessarily re-cycling but re-using some aspects of the building and some pieces of material or equipment or whatever you can, to either use in the same project for additions or maybe to use in a new project. If you demolish something, you can use it....". LQS(2) further elaborated on how certain materials are re-used by stating that "...when buildings are renovated and there is due care taken when certain building items are taken out such as doors, window frames and more here in Cape Town when older buildings are being demolished, old sash windows are taken out very carefully because they just don't make them like that anymore. There is a resale market for the re-use of certain types of elements, especially timber....". This aligns with the definition of circular buildings as structures that follow the principles of the circular economy throughout their design, planning, construction, operation, maintenance, and eventual deconstruction (Pomponi and Moncaster, 2017). A key aspect of circular buildings is the incorporation of circular design principles for components such as facades, windows, doors, and floors, which are designed to be easily disassembled, reused, and adaptable.

Most interviewees also mentioned the term 'green construction' when explaining circular construction, and JQS (1) was one of them. JQS (1) said, *"My understanding of circular construction is being conservative with building materials. I want to call an entire process green construction, where you try to minimise waste and reuse as many materials as possible. Even the material you use, you try to use as little of it as you can but still get the maximum output of the material"*. The same interviewee also stated, *"...There is an architectural process where you design a house so that it uses as little electricity as possible; therefore, you try to use as much natural lighting as possible and shading. So basically, designing a home so you can minimise your use of air-conditioning and heaters as much as possible. Circular construction is a process where you try to minimise waste, greenhouse gases, etc."* These findings are alike with the previous study which stated that buildings have a variety of installations, such as those for heating and cooling because the usage phase is where buildings have the most significant footprint impact (Jiang et al., 2022). Therefore, installation-focused circular solutions are considered during the design stage, concentrating on energy efficiency and the implications for material resources.

Theme 2: The attitudes of quantity surveyors on circular construction practices

All of the respondents expressed the belief that the integration of circular construction methodology in South Africa will enhance the sustainability performance of the construction sector. LSQS (1) contends that the construction industry is notorious for its significant environmental impact, and there has been little progress in enhancing sustainable practices. Through our consistent adherence to conventional practices, we have failed to meet our obligations. We are agents directly responsible for the degradation of the Ozone layer. The current level of sustainability efforts is insufficient. Furthermore, LQS (2) said that *"Natural resources are limited in quantity. Learning to reuse is crucial. My strong conviction is that design approaches should take into account this, particularly those who may create for the sake of resale. The consideration of the future occupants of the structure is crucial. Therefore, I am of the opinion that sustainability will serve as the primary impetus for any law enacted under the façade of sustainability"* Furthermore, our discovery aligns with the literature that asserts the use of recycled building materials as a facilitator for enhancing the sustainability of the construction industry (Kylili and Fokaides, 2017).

The financial implications of implementing circular building methods in South Africa were discussed by many participants. The LQS analysis (1) stated that the adoption would enhance sustainability. Nevertheless, there will be some constraints, that now restrict its use to large construction firms and developers located in major urban areas. Owing to the limited understanding in South Africa, the initial

costs of doing this may be higher in comparison to other nations that have already mastered the basics and achieved significant savings. However, some respondents acknowledged that a primary factor motivating them to advocate for circular building processes as Quantity Surveyors is the potential decrease in construction materials need. The respondent, who is also the proprietor of a private Quantity Surveying business, expressed dissatisfaction with the pro-rata pricing structure. Consequently, if the cost of a project is lower, they also get a lower income. JQS (1) concurred with SQS (1) on the reasons why certain Quantity Surveyors may be reluctant to adopt circular construction practices. They argue that as freelancers, the impact on their finances would be more detrimental than beneficial. This is because the introduction of cheaper materials or labour automatically results in a decrease in the value of the proposed project. Consequently, your share of the project value is diminished, resulting in a decrease in your compensation. The annual and sustainability report of Skanska highlights waste management, material circularity, and resource efficiency as key priorities for the company in its cost reduction efforts (Skanska, 2021).

SQS (1) was the only respondent who, in their perspective, further expounded upon another adverse consequence of circular building methods concerning sustainability. The use of circular building methods results in a reduction in manufacturing activities, therefore contributing to the mitigation of pollution. Nevertheless, these methods include a drawback since they will result in the replacement of the current industries. For instance, by returning zinc and steel waste to recycling facilities, further production will be avoided. Despite reduced material prices, the implementation of circular construction will have a beneficial impact on employment creation (Horbach et al., 2015). The results of this subject indicate that the respondents had a favorable attitude towards the integration of circular building processes, despite their limited understanding and experience. It is believed that by implementing certain practices, particularly the reuse of certain construction materials, prices may be reduced, thereby pleasing clients, even if it results in lower earnings for some quantity surveyors.

Theme 3: Quantity surveyors' perspectives on circular construction practices

When asked about the impact of implementing circular construction protocols on the characteristics of the quantity surveying profession, the majority of respondents hold the belief that it will have a positive effect. *"Yes, it will improve the service delivery of Quantity Surveyors and enhance their value to projects,"* said SLQS (3). Quantity Surveyors are highly suitable agents to promote and support sustainable practices. Furthermore, SQS (2) concurred by stating, *"Certainly, it will be more convenient to persuade clients about alternative construction techniques in order to reduce construction and maintenance expenses."* Consequently, the expertise of Quantity Surveyors in circular building methods would augment their responsibilities, particularly in an advising capacity. LQS (1) concurs with this statement by stating, *"...I believe that the role of the quantity surveyor may undergo some changes."* They may be designated in a more prudent statutory framework to provide guidance on the techniques and procedures to use in order to get the appropriate materials, therefore enabling them to carry out their cost-related tasks.

When questioned about the potential evolution of the quantity surveying profession, the primary issue emerged as the employability of Quantity Surveyors. SLQS (2) and SQS (1) held contrasting perspectives on circular construction and its impact on Quantity Surveyors due to the potential of innovative technologies for cost estimation and project management in building projects. The SLQS (2) acknowledges and supports the shift, asserting that their purpose is not to oppose technology, but rather to accept and use it. As Quantity Surveyors, it is imperative that we engage with technology and recognise the advantages it offers in enhancing our job performance and effectiveness. Having a clear understanding of the value, we may avail ourselves of several advantages. By recognising the presence of a danger, we persist in our efforts to combat it. It is worth noting that while we persist, our rivals are already adopting and collaborating with this strategy. SQS (1) disputes this matter by asserting that employment in the field of quantitative surveying would be affected. The quantity surveyor is still expected to do their necessary responsibilities, including overseeing construction and controlling costs incurred in building projects.

When questioned about the readiness of Quantity Surveyors to assume a crucial function in this evolving period, unanimous agreement was reached, contingent upon their participation in a forum to offer guidance on circular building methodologies. Furthermore, the customer demands a project that integrates circular building methodologies. John Q. Smith (1) elaborates by stating, *"In all honesty, unless there are significant changes in the profession, I do not anticipate that happening."* Unless the

Architect advocates for circular building techniques, we will not be able to implement them since we rely only on their blueprints. Indeed, it is the prevailing situation inside my organisation. However, the situation is worse for us juniors since our voices are disregarded. But, we are more fervent about turning green. LQS (2), a senior professor, concurred with JQS (1) that the younger and mid-level generations will exhibit more enthusiasm in advocating for circular building methods. He deduced that the reason for this is because *“traditional Quantity Surveyors, specifically the older generation who may be nearing the end of their careers, may exhibit some reluctance to acquire new knowledge.”* Elderly canines and novel manoeuvres. Nevertheless, I have seen that younger Quantity Surveyors, influenced by their generational mindset, tend to exhibit activist behaviour.

The majority of respondents indicated that the responsibilities of the Quantity Surveyor will remain mostly same. They attribute the responsibility of promoting circular building techniques to other stakeholders, namely the Architect. SLQS (1) further explained that the responsibility of incorporating circular practices is mostly with the designer, while the QSs are primarily focused on the characteristics of the architectural design. Our job is contingent upon the specific design that someone has created for us. Our impact will be negligible since it is contingent upon the designs' chosen building methods, so we will remain unaffected by any alteration. Implementing circular building practices is beneficial for the environment. However, the quantity surveying industry falls short of this goal since our primary responsibility is to calculate construction costs.

Furthermore, prior research suggests that architects play a crucial role in implementing circular economy principles in architectural projects (Kanters, 2020). Research was conducted to evaluate the variables that hinder the readiness of quantity surveyors to assume important roles in projects that include circular building techniques. The responses to this section mirror those of the preceding question, in which participants were queried about the preparedness of Quantity Surveyors to assume a crucial function in circular building projects. Consistent with the preceding statement made by SLQS (1), JQS (1) emphasises the limitations of Quantity Surveyors in their expertise on circular building projects. In addition to schooling, Quantity Surveyors (QSs) do not possess the role of designers; their responsibilities are limited to cost estimation and design.

This platform caters mostly to architects, civil engineers, and structural engineers. They possess the responsibility for designing and constructing the structure of anything. The decision is taken to create a building using 60% recycled materials. Once this design is finalised, the Quality Assurance (QS) requirements must be met, regardless of the decision to do so, and the associated costs must be calculated. Furthermore, the contractor must adhere to the prescribed procedures and ensure their proper execution. According to the interviewees, Quantity Surveyors perceive their involvement in promoting circular building techniques to be restricted. This researcher suggests that Quantity Surveyors may possess a lack of comprehensive understanding of recycled materials. In addition to education and awareness, LQS (2) stresses that organisations like ASAQS and any volunteer organisation that plays a crucial role in promoting a profession should consider it their responsibility if they deem sustainability to be a worthwhile objective. In developing countries such as ours, sustainability is typically seen as a desirable but not essential goal.

The analysis of this topic leads to the conclusion that the customer and architect have a greater degree of influence in promoting circular building techniques in projects. Subsequently, the Quantity Surveyor has the duty of determining the cost of the project by considering the architect's specifications and any other demands provided by the customer. Nevertheless, it is also evident that Quantity Surveyors possess a strong desire to assume a more significant position but being prohibited from doing so.

Recommendations

The study recommends a multi-faceted approach to improving the understanding and application of circular economy principles in construction. The study emphasises the need for targeted training programs and workshops tailored for quantity surveyors to bridge knowledge gaps. Incorporating circular construction concepts into the curricula of built environment programs is also advised to equip future professionals with the necessary skills. Furthermore, the research suggests enhancing collaboration between industry stakeholders and educational institutions to foster innovation and encourage the adoption of sustainable practices in construction projects.

Conclusion

Although the research acknowledges that quantity surveyors have a basic understanding of circular building ideas, it also highlights a notable deficiency in their comprehensive understanding and practical implementation of these principles. This discrepancy underscores the pressing need for focused educational and professional development programs to improve their proficiency in this field. To promote the use of circular building techniques, it is essential to overcome limitations such as economic constraints, regulatory obstacles, and the absence of standardised evaluation tools. The study proposes a cooperative approach involving all parties involved to create and execute plans that empower quantity surveyors to take the lead and introduce innovative practices that promote sustainability and resource efficiency in construction projects. This will ultimately contribute to the industry's shift towards a more sustainable and circular economy.

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Exploring the Use of Cloud Computing Technology in Construction Bid Automation

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Abstract

The purpose of the study was to explore the use of cloud computing technology (CCT) in construction bid automation by examining the benefits and challenges of its adoption in automation. The specific objectives were to outline the benefits of CCT in automated bid preparation through improved data management and to identify the challenges associated with using cloud computing in automated bid preparation. A systematic literature review of 32 relevant studies was used to gather the current knowledge on cloud computing in the construction industry from the literature. Key highlights of the findings indicate five key benefits of cloud computing such as massive storage capability, economic benefits, on-demand scalability of computing resources, facilitating collaborative practice, and a secured platform that will improve data management and enable seamless and effective automation integration into construction bid preparation using appropriate emerging technology. However, challenges like latency issues, trust, data privacy and security, data availability and governance impede its wide adoption. This paper brings novel knowledge, such as using cloud computing to enable automation integration in construction bid preparation. The paper also identifies some benefits of CCT in construction bid automation and discusses the challenges.

Keywords: Automated Bid Preparation, Cloud Computing Technology, Data Management, Digitalisation, Systematic Review.

Introduction

The construction industry faces many challenges that have hindered its growth and led to extremely low productivity levels compared with other industries such as manufacturing (Chui and Francisco, 2017). The construction industry is one of the world's least digitised industries, and most stakeholders acknowledge the age-long culture of resistance to change (Young et al., 2021). The lack of digitisation and the industry's overly manual nature make project management more complex and unnecessarily tedious (Delgado and Oyedele, 2021a; Bello et al., 2021). Cost inefficiencies, project delays, poor quality performance, uninformed decision-making, and poor productivity have all been associated with the construction industry's lack of adequate digital expertise and technology adoption (Abioye et al., 2021). Additionally, key activities such as bid preparation have become overly complex and time-consuming.

Bidding is the process many construction clients use to obtain the programme and price for building a project (Brook, 2004). Bidding simply refers to the process of making an offer to a project client for the opportunity to be awarded a contract. Bid preparation is one of the stages in the bidding process that requires extensive information and document exchange (Laryea, 2011). According to Cusumano et al. (2022), in Sweden, the current bid preparation processes by most construction firms are manual, complex, and time-consuming, and these are characterised by inefficiencies such as missing documents, data repetition, and ambiguity of content and meaning. These inefficiencies result in substantial transaction costs. Aggregating input data (for example, data on the cost of materials, labour, and quotes from subcontractors to estimate the total project cost for the bid) for bid preparation from numerous sources is also a component of this process. The result is that the expense associated with bid preparation activities rises to 2% of the total revenues of a typical construction firm as stated in a study by Ekström and Björnsson (2000), in the US. The significance of this percentage is underscored by the construction industry's slim margins and intense competition.

Automation has become a vital aspect of modern bid preparation processes in the construction industry (Heo et al., 2024). Automation refers to using technology and software to perform tasks and processes with minimal human intervention. The use of technology to streamline and optimise various activities in bid preparation can greatly improve efficiency, accuracy, and overall project outcomes (Choi et al., 2021). However, Cusumano et al. (2022), in Sweden, examined the potential application of AI in automating bid processes and discovered that though AI could effectively facilitate bid automation and knowledge transfer from production to new tender projects, successful business value generation necessitates a higher level of digitalisation, well-structured databases, and access to historical bid data. Other challenges to successful AI implementation include a lack of standardisation, the need for new work methods, difficulties in interpreting results, user interface, and interoperability.

Cloud computing technologies have revolutionised several industries for several years (Bello et al., 2021) and according to Oke et al. (2023), cloud computing is one of the digitalisation principles used in some sectors like banking and health. Bello et al. (2021), highlighted that cloud computing acts as a catalyst for the adoption and advancement of other emerging technologies like Internet-of-Things (IoT) in the construction industry. For instance, cloud-based data centres can handle data from IoT devices in real time to deliver critical consumer information and relevant advice (Ganesan et al., 2020). Cloud computing storage and delivery services have proven to be quite successful in lowering operational expenses (Broberg et al., 2008). Furthermore, cloud computing gives useful insights for improving decision-making because of its ability to evaluate massive amounts of data provided by IoT devices using high-performance computing tools (Ganesan et al., 2020). According to Tehrani and Shirazi (2014), cloud computing is an innovative solution that can help small and medium-sized businesses overcome productivity difficulties, such as expense, risk management, and a lack of storage capacity.

This review aims to explore the use of CCT in construction bid automation through improved data management and digitalisation for successful business value in automating bid preparation in the construction sector. By examining the existing literature, this review provides valuable insights into the capabilities of cloud computing, the benefits accruable and challenges thereof in using CCT.

The primary objectives that guided this research work are:

- To outline the benefits of CCT in automated bid preparation through improved data management.
- To identify the challenges associated with the use of cloud computing in automated bid preparation.

In spite of advancements in CCT, extant literature indicates a lack of thorough review of how cloud technology facilitates automation in construction bid preparation. This study explores the potential of leveraging cloud computing technology to drive digitalisation and improve data management in construction bid automation. This creates an opportunity for construction bidding practitioners and researchers to explore and develop new insights.

The paper begins with an overview of cloud computing technology and digitalisation and subsequently gives a comprehensive account of the review methodology employed in the study. A content review of the benefits and challenges of using CCT in construction bid automation is also presented, and finally, gaps and future research directions are discussed.

Literature Review

Cloud computing technology and digitalization

Digital technologies have become increasingly prevalent in today's practices in several sectors, revolutionising the way projects are managed and executed (Chui and Francisco, 2017). In recent years, it has become increasingly clear that the construction sector must adopt digitalisation and swiftly improve its technical capabilities, particularly in light of the current labour shortages, the COVID-19 epidemic, and the necessity of providing sustainable infrastructure. (Delgado and Oyedele, 2021b; Gbadamosi et al., 2019; Zaher et al., 2018). Cloud computing technology (CCT) has become one of the digitalisation principles used in some sectors and has revolutionised several industries for several years (Bello et al., 2021; Oke et al., 2023).

CCT marks a major transformation in the management and utilisation of hardware and software resources. The introduction of Service-Oriented Architecture (SOA), which forms the foundation of

cloud technologies, enables organisations to share both the physical and virtual components of their IT infrastructure. This approach allows for the reuse of computing resources and helps distribute computing costs. As a result, it considerably lowers both initial investment and ongoing operational expenses for computing infrastructure. The term "cloud computing" can mean different things to different individuals; for those in e-commerce, it refers to shareable Information and Communication Technology (Abedi et al., 2012). The National Institute of Standards and Technology (NIST), as referenced by Mell and Grance (2011, p.2), defines cloud computing as a model that offers convenient, on-demand network access to a shared pool of configurable computing resources—such as networks, servers, storage, applications, and services. These resources can be quickly allocated and released with minimal management effort or interaction with service providers. This definition, depicted in Fig. 1, encompasses five core features: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. It includes three types of service models: Software as a Service, Platform as a Service, and Infrastructure as a Service, as well as four deployment options: public, private, community, and hybrid.

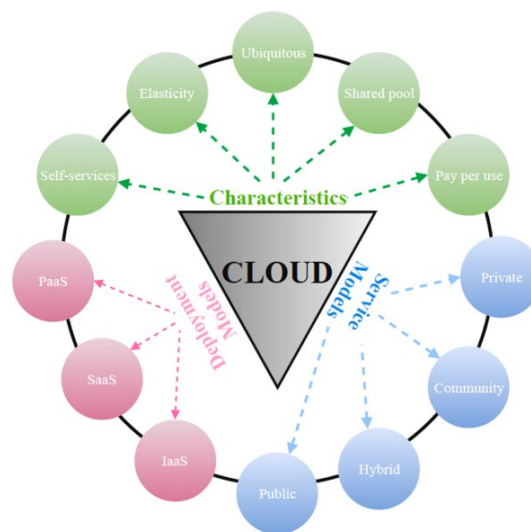


Figure 1: Summarised view of cloud computing (Bello et al., 2021)

Research Methodology and Method

There is a lack of comprehensive assessments that provide a complete perspective on the application of cloud computing technology as a digitalisation and data management mechanism for automating bidding processes in the construction sector. Insufficient academic texts pose a difficulty for researchers to thoroughly assess the effectiveness of different approaches in various settings at a quick scan. This study utilises the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) review method. This method ensures a highly logical process for defining keywords, selecting databases, determining which articles to include or exclude, and establishing a research timeline. Consequently, future researchers will find it straightforward to identify the precise contributions and limitations of this study. The review was carried out following the guidelines outlined by Page et al. (2021) about the PRISMA method.

Review approach

The study employed a systematic literature review (SLR) methodology, following the PRISMA guidelines. A systematic literature review (SLR) is a comprehensive examination of all relevant material in a certain field of study, conducted to answer a particular research topic (Moher et al., 2016). Each retrieved paper was checked by two reviewers who worked separately. The literature search was performed utilising the Scopus database as empirical comparison has found that Scopus offers more comprehensive coverage of sources than the Web of Science for fields of study outside of medicine and the physical sciences like construction-related literature (Hallinger and Kovačević, 2019; Mongeon and Paul-Hus, 2016). The search keywords were grouped into three: the first field concentrated on the subject area of investigation, specifically bid/tender process, bidding/tendering, and bid/tender process.

Field two focused on the construction industry, construction sector, construction, and built environment while field three centred on the technological context, including, cloud, cloud computing, cloud technology, cloud computing technology, automation, digitalisation, and data management.

The search strings used to validate the title, abstract, and keywords of the papers obtained from the Scopus database are:

(TITLE-ABS-KEY ("bid process" OR "tender process" OR "bidding" OR "tendering" OR "bidding process" OR "tendering process") AND TITLE-ABS-KEY ("construction industry" OR "construction sector" OR "construction" OR "built environment") AND TITLE-ABS-KEY ("cloud" OR "cloud computing" OR "cloud technology" OR "cloud computing technology" OR "automation" OR "digitalisation" OR "data management")) AND (LIMIT-TO (LANGUAGE, "English"))

The initial search produced 81 papers from Scopus. The review covered all document categories, including journal articles, books, book chapters, and conference papers. The Scopus search had no stated start date and this was done to allow the search engine to locate the earliest papers in the literature given the novel nature of the field and the possibility of not retrieving enough literature if the search was limited by a specific date, however, the search was limited to only documents written in English. Relevant terms and combinations of terms were used in the search.

After using established inclusion criteria to narrow the search string, a total of 75 relevant publications were identified. The publications were thereafter assessed by examining their titles and abstracts to ascertain their relevance to the research subject matter. After the title and abstract screening, 43 papers were excluded. These are papers that were not directly related to bidding or tendering in construction. Papers that were not directly related to or without a direct focus on cloud computing technology application, digitalisation, or data management in construction, and papers that did not satisfy all the inclusion criteria. Eventually, 32 publications were considered relevant to the scope of the study. The SLR revealed that some efforts have been made by researchers to explore the potential adoption and implementation of digital technologies in improving the bidding processes in the construction industry. For example, studies like Heo et al. (2024), Li (2022), and Kim and Jung (2019), have looked at some aspects of the bid preparation process mainly in terms of risk management, content review or requirement summary preparation, and bid pricing. However, the coverage of these studies is severely lacking in reviews that offer a comprehensive perspective on research activities concerning the application of cloud computing technology as an enabling mechanism of digitalisation for facilitating effective automation of bidding processes in construction procurement. This study is unique because none of the existing reviews are systematic, making it difficult to verify their robustness and the rationales behind the selected papers, search terms, and timeframes, which are crucial for developing future research. The research team utilised Microsoft Excel to acquire data by employing data extraction forms. Details such as the aim/objective, location (country) of the study, main findings/outcomes, limitations of the study, and future research recommendations were extracted with a data extraction form.

Analysis

The first analytical step involved a bibliometric analysis of article data. To accomplish this, the frequency of the included articles was examined by taking into account the publication year, publication keywords, and study location. An analytic framework was employed to ease the frequency analysis, allowing for the annotation of the included articles and the extraction of pertinent information on the research aims.

Further content review was done to ascertain some key highlights of current applications and the benefits of cloud computing for digitalisation and to also identify some challenges with adopting cloud technology.

Research Results and Discussion

The results of the analyses of the articles are in two main components - the bibliometric analysis results; and the content review results. Detailed discussion within each section is presented below.

Article distribution by study location and publication year

Figure 3 depicts articles distributed among several global areas concerning the application of cloud computing technology as a digitalisation and data management mechanism for automating bidding processes in the construction sector. This was obtained for some papers from the stated locations of the study in the papers, and others from institutional addresses or affiliations of the authors who are associated with the publications that are included. Figure 3 displays research completed in at least 18 countries worldwide, focusing on digitalisation and cloud computing technology applications. Among these countries, South Korea has the most studies, with 7 publications. South Korea is the primary contributor to research on leveraging cloud computing for digitalisation for effecting automation integration in construction bidding processes. Germany and Sweden rank second in terms of their contribution, with three publications each. China, Nigeria, Portugal, and Switzerland made two publications each. All other countries contributed a paper each.

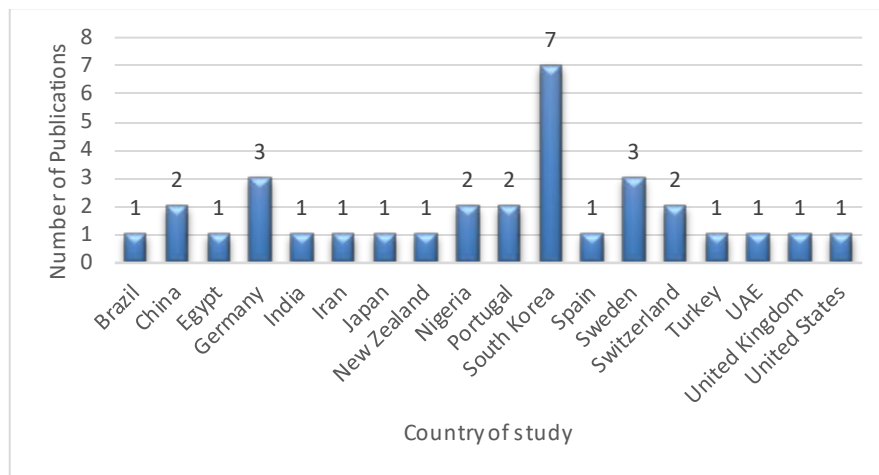


Figure 3: Article distribution by study location

Figure 4 illustrates the number of papers published from 2012 to 2024. The data shows a relatively stable trend with minor fluctuations until a significant increase in 2021, followed by a slight decline and balance in subsequent years. This review covers up to the second quarter of 2024, likely, by the end of the year, the number of published articles is expected to continue the upward trend seen in previous years. This increase highlights the growing global interest in cloud computing and its applications in construction within the research community.

In subsequent years, while the initial surge in publications slightly declined, the continued interest in cloud computing and its applications in various fields, including construction bidding processes, remains evident. This indicates an ongoing recognition of the value and potential of cloud technologies in transforming traditional practices.

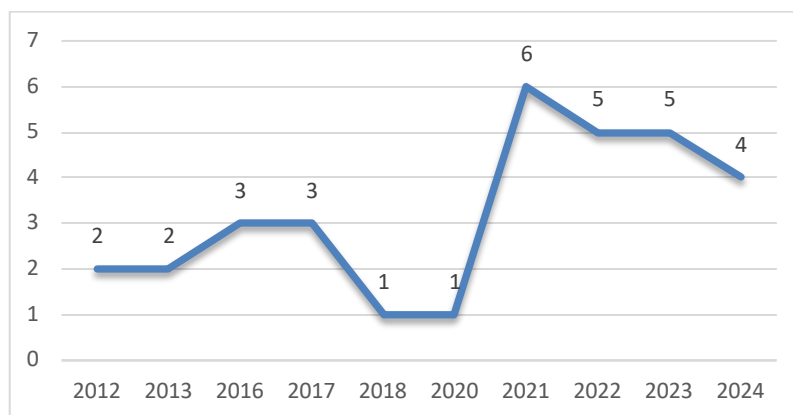


Figure 4: Article distribution by year of publication

Content review of benefits and challenges of using cloud computing technology (CCT) in automated bid preparation

Benefits/Opportunities

While the application of cloud computing in the construction business is an emerging area, it presents several opportunities. The SLR identified some benefits of CCT for driving digitalisation and improving data management in facilitating the automation of construction bid preparation processes as discussed below;

Massive storage capability

As indicated in a case study in Sweden by Cusumano et al. (2022), where they examined AI applications for automating tender processes. They discovered that while AI and digitalisation can facilitate tendering and the transfer of knowledge from production to new tender projects, successful business value generation necessitates a higher level of digitalisation, well-structured databases, and access to historical bid data.

Bid preparation is one of the stages in a construction project that requires extensive information and document exchange (Laryea, 2011). The current bid preparation processes are characterised by manual approaches with inefficiencies such as missing documents, data repetition, and ambiguity of content and meaning. The use of emerging technologies like AI and machine learning will require access to quality historical data to achieve the desired results in automated processes. Data that would typically consume hundreds of gigabytes on a conventional computer can be managed more efficiently with cloud storage. Traditionally, manually storing bid data has been inefficient due to the large volume of data and the substantial physical infrastructure needed for on-premises storage. Furthermore, on-premises storage necessitates in-person access to the data. In contrast, cloud storage enables remote storage and retrieval of data without limitations related to space or time. Therefore, cloud storage presents a valuable opportunity for streamlining and enhancing the data management process.

Economic benefits

Cost is a major obstacle for construction firms in adopting IT solutions due to their typically low-profit margins (Kumar et al., 2010). These firms are constantly looking for ways to reduce both infrastructure and operational expenses. The construction industry is often unsuited for extensive IT infrastructure, which demands significant expertise and management training. CCT offers a solution by allowing construction businesses, particularly small and medium-sized enterprises (SMEs), to access advanced computing resources and applications that would otherwise be prohibitively expensive. This can lead to a reduction in overall project delivery costs, providing construction firms with a competitive advantage and enhancing their operational efficiency. Additionally, cloud computing's pay-as-you-go model eliminates the need for ownership and ongoing operational costs, thereby increasing flexibility.

Facilitating collaborative practice

Construction projects involve multiple project teams, and the bid preparation process is similarly complex, with various business reporting models and documentation stored in separate silos (Li and Ma, 2016). This dispersed data often hampers stakeholders' ability to make timely and critical decisions during the bidding process. As a result, this fragmentation can cause poor planning, longer bid preparation periods, cost inconsistencies, and a reduced Return on Investment (ROI). Cloud computing addresses these issues by providing a centralised repository for bid data, offering a comprehensive solution that improves both the efficiency and structure of the bidding process. By centralising access to current project data, cloud solutions facilitate greater team collaboration and ensure that the bid team remains organised and cohesive.

Scalable computing resources available on demand

Cloud technology allows firms to acquire computing resources on a service basis, tailored to the specific needs of different phases of a construction project. Previously, securing higher-capacity infrastructure required substantial capital investment, which is no longer cost-effective for short-term requirements. Moreover, sudden spikes in demand might not allow enough time for purchasing and setting up new

infrastructure. Cloud computing provides access to high-performance servers equipped with robust Central Processing Units (CPUs), Graphics Processing Units (GPUs), and ultra-fast Solid State Drives (SSDs) at competitive prices. This advantage enables small and medium-sized enterprises (SMEs) to compete on equal footing with larger companies without the need for significant initial investments. For instance, Alreshidi et al. (2018), utilised cloud services scalability to develop a BIM-based model for governance.

Secure platform

Security in the cloud has evolved significantly, incorporating advanced measures such as encryption, up-to-date security software, cyber insurance, and regular security audits. Most small and medium-sized enterprises (SMEs) in the construction industry cannot afford the level of data protection available with cloud services through their in-house systems. The threat of data breaches, such as those from Cryptolocker ransomware, has further highlighted the advantages of cloud storage for safeguarding project data. Additionally, achieving the same level of system availability and uptime that cloud system providers offer is prohibitively expensive for construction firms to implement with their infrastructure (Bello et al., 2021).

The Systematic Literature Review (SLR) indicates that, while cloud computing offers numerous benefits, it has not yet been directly applied to address the low levels of digitalisation needed for automating construction bidding processes. However, there have been efforts to utilise cloud computing in related fields. For example, in supply chain management within the construction industry, cloud technology has been applied to address issues with uncoordinated traditional material supplies that often lead to delays. Ko et al. (2016) utilised cloud platform-as-a-service technology to track the movement of materials on construction sites, offering SMEs a more cost-effective alternative to conventional tracking systems. Similarly, a cloud-based system integrated with RFID was introduced by Sahin et al. (2017), to improve the visibility and traceability of materials in the construction supply chain. Hemanth et al. (2017), developed a cloud-based supply management system to tackle communication problems and improve the accuracy of information transfer in the precast sector. Grilo and Jardim-Goncalves (2013) leveraged both public and private SaaS platforms to enhance stakeholder collaboration, leading to more streamlined procurement processes. Fathi et al. (2012), introduced Context-Aware Cloud Computing Information Systems (CACCIS) to offer precise and relevant information to participants in the construction supply chain. Gong and Azambuja (2013) employed Google Fusion Tables, Google Maps, and Google Earth to manage supply chain data cost-effectively. Additionally, cloud computing has found applications in other areas such as construction waste minimisation, safety, energy management, and project management informatics (Bello et al., 2021).

The review findings indicate that cloud computing is becoming a significant focus of research in the construction industry, as evidenced by the growing interest in the field (Bello et al., 2021). Cloud computing offers numerous benefits, including powerful data analysis capabilities, vast storage options, and affordable and easy access to bidding information. This review also emphasises that cloud technology can be utilised across different phases of the construction project lifecycle, including feasibility, design, and construction stages.

Challenges

Although cloud computing technology is highly relevant for advancing digitalisation and automating construction bidding processes, the SLR reveals some challenges that hinder its widespread adoption;

Possible latency issues

Adopting cloud technology may not always ensure the transfer rates and response times needed for certain time-sensitive applications, which could stem from software design or network limitations. Effective design can help mitigate latency issues, and utilising distributed cloud architecture can minimise latency for specific applications. Recently, cloud-based applications are increasingly optimised for cloud environments, as they generally perform well within cloud environments. To address latency issues, Petri et al. (2015) have proposed using a hybrid cloud approach, where delay-sensitive components of an application are kept on-premises while other parts are hosted on public cloud services. Construction companies might also consider establishing dedicated connections with service

providers to avoid delays associated with internet-based transport. Additionally, selecting service providers with data centres closer to the company can reduce latency, as fewer network hops improve performance. Application Performance Monitoring (APM) tools can also help track network performance, enabling early detection and resolution of latency issues.

Trust, data privacy and security

The risk of vulnerabilities in cloud adoption is growing with the increasingly dynamic nature of security perimeters (Hay et al., 2011). In real-world scenarios, business partners frequently show reluctance to disclose their private and commercial information, including bidding documents, with third parties (Shin, 2010). Mahamadu et al. (2013) have highlighted security and privacy concerns as significant threats to the integration of Building Information Modeling (BIM) with cloud services. The construction industry is understandably cautious about storing design and financial data in shared resources, partly due to concerns about potential unauthorised access. This concern is often more psychological, stemming from the fear that unknown individuals might access the data. In reality, the most critical vulnerabilities are typically on the client side, as data breaches often occur due to issues such as employees using personal, potentially compromised mobile devices. Consequently, construction firms must implement robust organisational information protection measures to prevent information leaks. In instances of data breaches by service providers, information security and privacy regulations are enforced to ensure compliance (Hoover, 2013).

Data availability

Experiencing downtime with cloud-based technologies is not unusual, as no technology can be entirely infallible. Cloud providers might occasionally need to shut down their services unexpectedly, potentially rendering bidding data inaccessible. This situation raises concerns about the impact on the bidding data and an ongoing bidding process, especially if it occurs during a critical stage. To address these concerns, cloud providers typically offer a Service Level Agreement (SLA) guaranteeing up to 99.999% availability. Additionally, recent advancements in cloud technology involve the use of open-source tools to establish strategies for information representation (Bello et al., 2021). These developments aim to ensure compatibility between different cloud providers, facilitating data exchange and mitigating the risk of being locked into a single provider if it becomes unavailable.

Data governance

Construction projects involve multiple professionals, making it essential to clearly define the contractual relationships between stakeholders. This is particularly important because as data is contributed by various parties, questions of data ownership can arise (Wu and Issa, 2012). Since all parties have access to and are responsible for updating the data, determining the actual owner of the data can be complex. Additionally, the relationships among team members must be considered, especially regarding the exchange of information between different project participants (Redmond et al., 2012). For example, should the client be permitted to share data with the Engineer? It is necessary to establish specific access levels for various stakeholders involved in creating and managing bidding data. Applications utilising this data should incorporate proper access control features, rather than relying solely on cloud service providers to manage these controls.

Cost implication of long-term use

Long-term costs associated with using cloud infrastructure can be substantial, varying based on the deployment model. Initially, cloud Software as a Service (SaaS) pricing was based on time-based consumption, but advancements in cloud research have introduced market-based and personalised pricing models, leading to a variety of pricing options. While reserving cloud resources can offer favourable rates, ongoing improvements in ICT technologies are expected to further lower cloud service costs. It's important to note that costs differ across various cloud deployment models, even for the same construction company. For example, renting high-performance resources like graphics processing units for machine learning and analysis can be particularly expensive. Therefore, individual construction companies may need to perform a detailed financial evaluation of extended use for different cloud deployment options before fully transitioning to the cloud.

Increased likelihood of storing dark data

Cloud storage offers a convenient and cost-effective method for storing data, which has led to accumulating “dark data”. Dark data refers to information collected but not processed or analysed to derive meaningful insights. A significant portion of data generated by sensors remains unused, as the capacity to generate data often exceeds the capacity to analyse it. Much of this data is collected to meet regulatory requirements, and there is sometimes a belief that such data might be useful for future analysis. However, the value of data is often time-dependent; data that is not processed promptly can become insignificant, unnecessary, or outdated. Additionally, the costs associated with storing and managing dark data may become substantial, as considerable resources are spent on maintaining data that ultimately holds little relevance.

Threats of edge computing and associated technologies

Certain applications that require rapid processing and response times might not be ideally suited for distant, centralised cloud computing, which poses a challenge to traditional cloud models in the construction industry. This necessity to process data closer to its source has led to the emergence of Edge Computing (Khan et al., 2019) and associated technologies such as cloudlets, hierarchical cloud computing, mobile edge computing, and mobile IoT (Elazhary, 2019). Edge computing shifts processing capabilities closer to the data sources, thereby bringing cloud services more directly to the end users. However, Ai et al. (2018), suggest that while some applications are better suited to centralised cloud computing, others may benefit more from edge computing, as demonstrated by case studies in Zhang (2020), Li (2020), and Jin et al. (2020). This indicates that centralised cloud computing remains relevant despite the rise of these emerging technologies.

Conclusion

This study provides a comprehensive analysis of the ability of cloud computing technology to enable effective automation of the construction bidding process. The bibliometric analysis revealed the increasing global interest in this area, particularly in countries like South Korea, Germany, and Sweden, with significant growth in publications since 2021. The co-occurrence mapping highlighted key themes such as artificial intelligence, machine learning, and automation, in current research discussions within the construction industry.

The content review identified substantial benefits of cloud computing for automating bidding processes, including enhanced storage capacity, cost efficiency, collaborative practices, and scalability of computing resources. Additionally, cloud computing provides a secure platform for managing the vast amounts of data generated during bidding, helping construction firms streamline operations, reduce costs, and improve project outcomes.

However, the study also highlighted challenges impeding wider adoption, such as latency issues, data privacy concerns, data governance complexities, and the potential long-term cost implications of using cloud services. Furthermore, emerging technologies like edge computing pose potential threats to traditional cloud computing, indicating that while cloud technology is foundational, the industry must remain adaptive to innovations.

Overall, cloud computing holds immense potential to transform construction bidding processes by enabling greater automation, but addressing these challenges is crucial for its successful integration. Future research should focus on overcoming these barriers and exploring the role of emerging technologies in enhancing the automation of construction practices.

Knowledge Gaps and Recommendations

Despite the advantages of cloud computing in construction bidding, several knowledge gaps need addressing. Firstly, while cloud computing is beneficial, issues related to latency and performance remain underexplored. The impact of these issues on real-time data processing and decision-making in construction projects needs further investigation. Research should seek to identify solutions that minimise latency and improve the overall efficiency of cloud-based applications in construction.

The long-term financial implications of cloud computing are not thoroughly examined. Understanding the total cost of ownership for cloud services over extended periods is crucial, especially for small and medium-sized enterprises (SMEs). Future studies can provide a detailed analysis of these costs to help organisations make informed decisions about cloud adoption.

Data governance and ownership are also areas requiring more clarity. As multiple stakeholders are involved in construction projects, establishing clear guidelines for data access, control, and ownership is essential. Research should focus on developing frameworks to manage these aspects effectively, ensuring all parties have appropriate access and control over the data.

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Factors Hindering the Incorporation of Biophilic Design into Hospitals Within the South African Private Sector

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Abstract

Over the past decade, biophilic design has gained popularity as a sustainable approach to enhancing the health and well-being of building occupants in response to growing environmental and health concerns. However, doubts and controversies still surround the conceptualisation and implementation of 'nature' in research and practice. Notwithstanding ongoing research into biophilic design, there is still only a diminutive amount of information pertaining to the concept. Despite the necessity of biophilic design as part of buildings to create a healthy human environment for humans, hospitals seem to lack this vital aspect. The research aims to uncover the specific factors hindering the adoption of biophilic design elements in hospital environments. An interpretivist inductive approach was followed. This approach allowed for the exploration of unique dynamics and complexities within the South African private hospital sector that influence the incorporation of biophilic design. Three semi-structured interviews with open-ended questions were conducted with architects and designers with experience in hospital design. The findings indicate a noticeable increase in awareness among stakeholders regarding biophilic design. The requirement for specialised knowledge and expertise, maintenance concerns, financial implications, insufficient education about biophilic design, inadequate guidance from green building frameworks, and hygiene considerations within hospital settings were barriers identified to impede the successful implementation of biophilic design strategies. The small sample limits the generalisability of the findings; however, the study created a foundation for further research in this area. Each of the findings can be further unboxed in detail. A qualitative theory testing study with a larger sample could also benefit the future study. This study provides insight and recommendations to construction industry professionals, such as quantity surveyors and hospital stakeholders, to promote the integration of biophilic design. Overcoming the barriers and incorporating biophilic design represents an essential shift from traditional hospital design practices to modernised and improved healthcare. Understanding the benefits of biophilic design in hospitals and the barriers to it.

Keywords: Biophilic Design, Green Buildings, Healthcare Sector, Sustainability, Vegetated Buildings.

Introduction

In recent years, the concept of biophilic design has emerged as a compelling strategy for enhancing the well-being of building occupants while addressing pressing environmental concerns. This design approach integrates elements of the natural environment into the built environment, aiming to reconnect inhabitants with nature and promote social, physical, and mental health. As urbanisation accelerates and global health crises, such as the COVID-19 pandemic, underscore the importance of access to nature, architects, designers, and building owners are increasingly recognising the potential benefits of biophilic design (Zhong, Schröder, and Bekkering, 2021; Andreucci et al., 2021).

Despite the growing interest in biophilic design, controversies and uncertainties persist regarding its implementation and conceptualisation in both research and practice (Andreucci et al., 2021). This paper focuses specifically on the challenges hindering the incorporation of biophilic design principles into hospitals within the private sector in South Africa. While the broader benefits of biophilic design are well-documented, its application in healthcare settings remains relatively novel and presents unique challenges.

Urbanisation's rapid pace demands solutions to counteract environmental degradation, prompting the emergence of biophilic design to reintegrate nature into built environments ((Panagopoulos, Sbarcea and Herman, 2021). This approach not only addresses ecological concerns but also holds promise for promoting healing and well-being in healthcare settings (Zhong, Schröder and Bekkering, 2021). Despite evidence supporting its benefits, biophilic design remains underutilised in hospital construction, with designers often neglecting its potential (Moslehian et al., 2023). Understanding the barriers to its adoption is crucial for integrating biophilic principles into hospital design globally. This study aims to identify obstacles preventing the widespread adoption of biophilic design in private-sector hospitals, filling a critical research gap. By elucidating these challenges, it seeks to inform future design practices, fostering healing environments that prioritise patient well-being.

South Africa stands at the forefront of biophilic design adoption within the healthcare sector, exemplified by the unveiling of groundbreaking facilities such as the Christiaan Barnard Memorial Hospital in Cape Town and the Cintocare Hospital in Pretoria (Growthpoint Properties, 2021). However, despite this progress, significant barriers impede the widespread adoption of biophilic design principles in private-sector hospitals. Understanding and addressing these barriers are crucial for realising the full potential of biophilic design in improving patient outcomes and enhancing the healthcare environment.

The challenges inhibiting the integration of biophilic design into hospital settings encompass various aspects, including cultural and social attitudes, design complexities, lack of education and documentation, perceived costs, and absence of standardised frameworks. Cultural and social attitudes towards nature, coupled with resistance to change within the healthcare industry, pose significant obstacles to adopting biophilic design principles (Tekin, Corcoran, and Gutiérrez, 2022). Furthermore, misconceptions and ambiguities surrounding implementing biophilic design hinder its uptake among professionals and stakeholders (Bratman et al., 2019).

This paper aims to identify and understand the multifaceted barriers preventing the successful incorporation of biophilic design principles into private sector hospitals in South Africa. By conducting in-depth interviews and analysis, we seek to elucidate the complexities of these challenges and propose strategies for overcoming them. Through our research, we aim to contribute to the existing body of knowledge on biophilic design and provide practical insights for policymakers, healthcare providers, and design professionals.

In addition to the main aim of the study, which was to identify the factors obstructing the integration of biophilic design in private sector hospitals in South Africa, the research included several supplementary objectives:

- To explore the potential effects of biophilic design on patients.
- To consolidate an account of possible barriers to the implementation of biophilic design.
- To contribute to potential solutions for implementation.
- To evaluate the extent of awareness among stakeholders in private sector hospitals concerning the beneficial qualities of biophilic design.

Literature Review

Biophilic design

Biophilia, defined as the “psychological orientation of being attracted to all that is alive and vital” (Dias, 2015), addresses the diminishing natural environments due to urbanisation reflected in the built environment (Kellert & Calabrese, 2015). In response, the concept of biophilic design and building emerges, which entails integrating natural elements into constructed environments to strengthen the connection between individuals and nature in urban settings (El-Darwish & Jaheen, 2021).

Incorporating of biophilic design into healthcare environments, as highlighted in the debated discourse, offers advantageous outcomes for both patients and staff. This integration fosters psychological and cognitive benefits, enhancing staff productivity while reducing stress. Additionally, it mitigates the negative impact of hospital spaces on patient morale and serves as a catalyst for patient recovery (Zhao et al., 2022). While extensive research emphasises the positive impact of biophilic design in hospitals, a global trend reveals that hospital designers often neglect these benefits, leading to limited incorporation of such designs in healthcare facilities (Moslehian et al., 2023).

The term “Biophilic Design” was introduced between 1964 and 1984 alongside the concepts of “Biophilia” and the “Biophilic Hypothesis.” While Biophilia and the Biophilic Hypothesis centre on the human connection with biodiversity and its positive effects on cognition, psychology, and physical well-being, Biophilic Design adopts a more integrative approach. It is defined as an innovative design strategy aimed at enhancing the human-nature connection in inhabited spaces, with the goal of fostering beneficial welfare outcomes (Yassein & Ebrahiem, 2018).

Biophilic design parameters include natural elements such as spaciousness, water, greenery, natural colours, thermal comfort, quietness, fresh air, and natural light, all of which are incorporated into the built environment. According to Tekin et al. (2023), incorporating these elements in hospitals creates a remedial and soothing atmosphere for patients and staff. This design approach is not limited to interiors; architects can extend it to hospital layouts, incorporating gardens and water bodies around facilities. This allows individuals to step outside, enjoying the combined benefits of biophilic design parameters.

Perceived benefits of biophilic design in hospitals

Providing aid for mental disorders

Research findings, as presented by Moore et al. (2018), found that the physical healthcare environment positively impacts mental health outcomes. The data collection utilised a comprehensive search strategy, encompassing thirteen databases, including PsycINFO, Embase, and MEDLINE, spanning from inception to 2016 December. Additionally, grey literature and various sources, such as Google and the WHO trials registry, were also investigated. The study focused on adults and older adults in high-income countries, excluding rural or low-/middle-income settings.

Lower overall mortality rates

Supported by McSweeney (2014) and Kuo (2015), exposure to nature offers various health benefits, including lower mortality rates, faster recovery, reduced blood pressure, decreased reliance on medication, and diminished pain. Consequently, there is an increasing necessity to re-evaluate hospital design to incorporate these insights. McSweeney's (2014) study provides a thorough overview of indoor nature exposure (INE) and its potential health benefits, employing a scoping review methodology. This approach enables the integration of evidence from various disciplines, thereby enhancing the understanding of the effects of INE on health. However, typical limitations associated with scoping reviews are recognised, including potential methodological challenges such as insufficient participant characteristics, realism of exposure, and limited qualitative data capturing individual experiences. The constraints of the methodology are also acknowledged, as it does not permit critical appraisal of evidence quality, highlighting the possibility of publication bias. The study's restriction to English-language articles may also have excluded relevant work conducted in other languages and regions.

The abstract does not explicitly mention the location of data collection. Nevertheless, it is implied that the data is derived from diverse academic articles and studies conducted in various geographical locations and settings, encompassing indoor spaces with integrated nature elements. The research provides an overview of indoor nature exposure (INE) and its potential health benefits using a scoping review methodology. This approach, which incorporates evidence from multiple disciplines, improves the understanding of the effects of INE on health. Despite the breadth, scoping reviews have inherent limitations. The study acknowledges methodological concerns, such as the absence of participant characteristics, exposure realism, and limited qualitative data for individual experiences. Critically, the scoping method doesn't permit the appraisal of evidence quality, and potential publication bias is acknowledged, considering studies with negative results might be underrepresented. The English language restriction may have also excluded pertinent work in other languages and regions.

In Kuo's research (2015), the data collection involved compiling studies and literature exploring the connection between nature exposure and human health. The studies examined a range of environmental factors, physiological and psychological states, behaviours, and conditions associated with nature exposure, clarifying their implications for specific physical and mental health outcomes. The data sources consisted of experimental and observational studies, as well as reviews and meta-analyses, with the aim of providing a comprehensive understanding of the potential pathways linking nature and health (Kuo, M., 2015). The text does not explicitly specify the data collection location. However, it implies that the data is derived from diverse studies conducted in various natural settings such as urban green spaces, parks, gardens, forests, and agricultural lands across different geographic regions.

The article thoroughly examines potential connections between nature and health, proposing enhanced immune functioning as a promising central pathway. While acknowledging this, it recognises the existence of other potential pathways. The conclusions are based on a literature review, which underscores the value of the approach while also recognising limitations, such as biases in the included studies and the potential for undiscovered pathways. The article points out self-selection bias in the relationships between green environments and health, stressing the necessity for more rigorous research designs to definitively establish causality. Therefore, additional research is crucial to validate the proposed central pathway and to investigate other possible mechanisms linking nature and health.

Overall improved well-being

Hospitals, recognised as crucial hubs for health recovery, are increasingly focusing on designing environments that foster well-being by integrating natural elements, as emphasised by Zhao et al. (2022). Research by Bratman et al. (2021) and Abdelaal & Soebarto (2019) indicates that interaction with nature not only alleviates stress but also positively impacts spiritual, mental, and emotional health, inducing constructive changes in one's state. Zhao's study on biophilic design in hospital environments employed data from a literature analysis and a case study. The literature review examined the positive effects of nature on human health, highlighting the principles and elements of biophilic design. The case study involved field research and structured interviews conducted in twelve national hospitals in China, each with a floor area of over 50,000 square metres. The aim was to evaluate the current implementation of biophilic design in healthcare settings, identifying existing deficiencies and shortcomings.

The case study focused on high-traffic areas within hospital public spaces, including the lobby reception, registration and payment zones, waiting areas, corridors, CT rooms, inpatient wards, and hospital lifts. The paper offers a comprehensive analysis of the importance of biophilic design in post-COVID-19 hospital environments and its role in sustainable development. Data collection included literature analysis and field research with structured interviews across the twelve Chinese hospitals. The literature review underscored the beneficial impact of nature on human health and the principles of biophilic design. The case study assessed the current status of biophilic design in healthcare environments, identified challenges such as the lack of natural elements and improper implementation, and proposed design solutions.

The research conducted by Bratman et al. (2021) and Abdelaal & Soebarto (2019) employed a conceptual model in a case study examining the impact of antidepressant prescriptions. Data collection comprised three steps: (1) identifying natural features (such as street trees), (2) calculating exposure based on the density of residential street trees, and (3) excluding considerations of dosage or interaction. The study analysed the correlation between decreased antidepressant prescriptions and the presence of more street trees, taking into account potential benefits like stress reduction and enhanced working memory.

Various research methods were utilised, including controlled laboratory studies, experimental fieldwork, cross-sectional studies, and longitudinal research, to investigate the relationship between nature experiences and mental health. Data were gathered through investigations into how natural experiences relate to mental well-being. The research examined different types of nature experiences across urban and rural settings, considering elements such as green spaces, blue spaces (aquatic and marine environments), and street trees or private gardens.

The study offers valuable insights into the potential mental health benefits associated with nature experiences, highlighting interactions with nature that are linked to improved psychological well-being and reduced risk factors for certain mental illnesses. However, it primarily presents correlational findings, and the causal mechanisms connecting natural exposure to long-term mental health outcomes are not yet fully understood. Additionally, the research focuses on urban contexts within the Global North, lacking insights into the duration of observed effects. Further investigations are essential to understand how the benefits of natural experiences may vary across socioeconomic statuses, preferences, cultures, age groups, and different locations. Despite these limitations, the evidence suggests that interactions with nature may serve as a psychological ecosystem service with positive implications for mental health.

Noteworthy examples of effective biophilic design integration in healthcare settings include the Cancer Centre at Guy's Hospital, Circle Hospital, and Alder Hey Children's Hospital. Additionally, Maggie's Centres, which offer healthcare services without medical treatments, serve as excellent illustrations of biophilic healthcare environments, as noted by Tekin, Corcoran, and Gutiérrez (2022).

Tekin, Corcoran, and Gutiérrez (2022) employed a systematic review methodology for data collection, conducting searches across six databases that included publications from 1973 to September 2021. The search was limited to English-language, peer-reviewed academic journal articles. Boolean operators were used in the search syntax to combine terms related to biophilic design, therapeutic environments, and well-being, as well as depression and anxiety. The data collection encompassed various countries, with four studies from the United States, three from Australia, one from the United Kingdom, and one conducted collaboratively by the UK and the Netherlands. While the systematic review methodology is robust, there are potential critiques; the inclusion criteria favouring English and peer-reviewed publications may introduce publication bias, potentially excluding relevant non-English or non-peer-reviewed research. The study's limited timeframe might omit recent findings, and varied research methodologies could introduce data heterogeneity, impacting conclusions. The predominant focus on cancer care settings may restrict generalizability to broader therapeutic environments.

Private sector hospitals

Private-sector hospitals, distinct from government-controlled facilities, encompass categories like not-for-profit or for-profit, international or domestic, and informal or formal (Klinton, 2020). Private hospitals in South Africa play a crucial role, constituting 21 percent of total beds, with a noticeable shift from public hospitals since 1990 (Chellan & Sibiyi, 2020). Modern healthcare often overlooks spiritual and mental health, gaining significance post-COVID-19. Private hospitals must evolve into therapeutic spaces addressing social, emotional, and psychological aspects. Biophilic design emerges as a solution, mitigating overlooked issues and fostering a more welcoming environment (Tekin, Corcoran, & Gutiérrez, 2022). Achieving this transformation requires a design shift towards more human-centred environments with a closer connection to nature.

Impact of cultural and social attitudes towards the incorporation of biophilic design in private sector hospitals

Despite more than 40 years of research demonstrating the benefits of access to nature for both human and environmental health, the integration of biophilic design is relatively recent, spanning only two decades (Abo Sabaa et al., 2022). This novelty encounters resistance within an industry that is traditionally resistant to change, leading to cultural and social barriers to its adoption. There remains considerable ambiguity among design and sustainability professionals regarding which specific aspects of nature benefit various groups, largely due to a misunderstanding of how to implement study findings (Bratman et al., 2019). Challenges arise from a disconnect between urban planning interventions, biophilic design principles, and the intended health outcomes, compounded by a lack of coordination across disciplines (Andreucci et al., 2021). Decision-makers in private sector hospitals frequently prioritise established practices, cost limitations, and efficiency over design considerations and nature-based opportunities, often overlooking patients' experiences (Tekin, Corcoran, & Gutiérrez, 2022).

The influence of perceived costs on the decision-making process regarding the integration of biophilic design features in private sector hospitals

Biophilic design, while valuable for healthcare, faces challenges in implementing due to financial constraints and limited research, especially in developing regions (Zhao, Zhan, & Xu, 2022). Obstacles in private sector hospitals arise during decision-making, influenced by cultural attitudes (Tekin, Corcoran, & Gutiérrez, 2022). Despite the challenges, research by Bolten and Barbiero (2020) emphasises that the incorporation of biophilic design improves patient outcomes, reduces stress, and increases job satisfaction for healthcare professionals. To effectively implement these design elements, it is essential to develop strategies to address perceived costs. Prioritising long-term benefits, even with upfront investments, can be justified, as seen in Ismaeil and Sobaih's study (2022) showing savings through sustainable materials. Overcoming perceived expenses, private sector hospitals can create healing spaces by prioritising biophilic design's long-term benefits, exploring cost-effective solutions, and educating stakeholders (Bolten & Barbiero, 2020; Ismaeil & Sobaih, 2022; Tekin, Corcoran, & Gutiérrez, 2022).

Possible improvements to the design and layout of private sector hospital facilities to facilitate the integration of biophilic design

Bolten and Barbiero (2020) contend that the integration of low environmental impact design with holistic design is essential for creating restorative environmental design and achieving true sustainability in healthcare settings. However, practice and research in this field are currently inconsistent. Some hospitals utilise natural materials without making appropriate selections or applying them correctly according to specific contexts, often lacking a systematic design philosophy to guide their choices. Alsunaidi et al. (2021) note that this results in a superficial reproduction of natural elements and a failure to recognise the benefits that natural environments provide to individuals. Incorporating natural elements, such as roof gardens and plants, in therapeutic medical settings can alleviate patients' suffering and anxiety (Biederman and Vessel, 2016). Research by Eisen et al. (2008) indicated that children of all ages and genders preferred nature-themed art over abstract art, with approximately 75% favouring natural scenes, such as beaches with waves or forests with lakes and deer.

In 2020, Dushkova and Ignatieva demonstrated that incorporating elements such as aromas, water features, visual comfort, natural sounds, real marine life, natural light, windows, greenery with outdoor views, outlook spaces, and a sense of personal control can enhance positive emotions and accelerate recovery. However, many hospitals lack a systematic design theory to guide the selection and application of these natural elements, resulting in a disconnect between current research and practice in this area (Alsunaidi et al., 2021). Skylights could be installed to introduce natural light into outpatient halls and corridors, which not only reduces patient stress and electricity consumption but also supports sustainability. Additionally, waiting rooms could feature floor-to-ceiling windows to create a seamless blend of indoor and outdoor spaces, allowing patients to enjoy views of the outside world while remaining comfortable indoors. Directional signs could be modified to feature colours such as green, blue, or yellow, and a small garden could be added to the waiting area to incorporate more natural elements into the design. The natural environment within wards could be enhanced by introducing comfortable lounges, sofas, soothing music with natural sounds, and features such as goldfish and potted plants. A forward-facing eave could be installed to provide patients with a sense of perspective, while movable louvres on the windows could help optimise lighting while minimising glare.

Hospital stakeholders

Stakeholders, integral to an organisation or project, possess varying responsibilities and influence its resolutions, proceedings, and success. The reciprocal relationship between organisations and stakeholders highlights their mutual impact and responsibilities (Barney et al., n.d.). In healthcare, stakeholders encompass a diverse range, including the insurance industry, physicians, pharmaceutical companies, patients, employers, and government agencies (Healthcare, 2011). Furthermore, healthcare providers, investors, patients' families, non-governmental organisations, research institutions, charities, the local community, employees, and the media also play significant roles (Zanchetta, 2022). The four P's model categorises Patients, Providers, Payors, and Policymakers as key stakeholders for every healthcare organisation (Lubbeke, 2019). The distinction between internal stakeholders, directly involved through employment or ownership, and external stakeholders, affected

by the organisation's activities, is crucial in understanding their dynamics and impact (Fernando, 2023; Leonard, 2018).

Stakeholders in the private hospital sector that are responsible for incorporating biophilic design

In healthcare, decisions impacting systems and sustainability involve policymakers and key stakeholders, including Patients, Healthcare Providers, and Investors (Vogel, et al., 2013). Nonetheless, a study by Gordonson (2018) explores how urbanisation disrupts the innate human-nature connection and advocates for biophilia in industrialised spaces. The study identifies barriers to biophilic design incorporation, including clients' limited awareness, the impact of urbanisation, and challenges in adapting biophilic strategies to build environments. However, a study conducted in 2018 (Gordonson, 2018) examines the adverse effects of urbanisation on the inherent connection humans have with nature and advocates for outcomes that promote biophilia in these highly industrialised environments through the utilisation and integration of biophilic strategies in the built environment. The various barriers to the incorporation of biophilic design identified in the study are outlined below.

Clients often restrain the integration of biophilic systems in their projects due to the added expenses conflicting with their imperative to minimise initial and design costs. The maintenance of biophilic design also incurs additional costs, demanding continuous efforts that clients may be unwilling to undertake. The scarcity and sporadic nature of biophilic design elements further contribute to their elevated procurement and acquisition costs. Clients often lack awareness and understanding of the value that biophilic design can bring to their projects. Furthermore, they may not recognise the return on investment associated with its integration. This issue is particularly pronounced among clients with multiple stakeholders who have differing objectives. In some instances, the physical space itself presents a barrier; certain buildings are situated in heavily urbanised areas where access to nature is severely limited. Additionally, the specific functions of older or traditional buildings can complicate the effective incorporation of biophilic design strategies.

The limited research on the long-term effects of integrating biophilic design in the built environment, combined with its scarcity, results in a lack of innovation and representation, which fails to stimulate demand and interest from clients and stakeholders. Despite conclusive research defining biophilic design, many designers and architects still misunderstand it, often equating it solely with introducing tangible natural elements like plants into the built environment. Design and architectural schools lack the comprehensive inclusion of biophilic design in their curricula, leaving architects, designers, and planners without the necessary competence for practicing and incorporating biophilic design.

Information on biophilic design is not centralised or readily accessible for a diverse array of professionals. Some architects and designers encounter misinformation due to miscommunication arising from language barriers, while others experience challenges in accessing information because of the methods used for dissemination. In a 2022 study in the HERD Journal, patient, visitor, and staff experiences in clinical environments were explored, recognising the psychological and physical benefits of natural elements. The study highlights the importance of addressing mental, emotional, and chronic illnesses and advocates for biophilic design as a potential mitigation strategy. However, it identifies a barrier: the inadequacy of current biophilic design frameworks, which lack standardised guidance, are often vague, and cannot be easily adapted to various functional, geographical, and cultural contexts.

Research Methodology and Method

The qualitative research methodology was suitable for the study. This methodology allowed for the exploration of the multifaceted factors that hinder the incorporation of biophilic design in South Africa's private sector hospitals through researcher engagement with healthcare stakeholders such as owners, architects, hospital administrators, and other relevant stakeholders. The methodology promised to provide insight into the intricacies, challenges, concerns, and suggestions related to biophilic design implementation, and thus allowed for a holistic comprehension of these factors considering the dynamic nature of the hinderances.

The selection of a qualitative research methodology, specifically in-depth semi-structured interviews, was well-suited to address the research objectives of the study. This approach was intended to yield rich and nuanced insights into the factors hindering the incorporation of biophilic design in hospitals within the South African private sector. In support of this choice, a study conducted during the COVID-

19 pandemic by Hindley et al. (2020) implemented a similar qualitative method in the form of expert interviews. In their research, in-depth semi-structured interviews were conducted with 7 hotel employees with managerial experience ranging between 3.5 and 16 years. The study focused on implementing biophilic design in back-of-house (BOH) workspaces within the hospitality industry, addressing issues such as lack of natural lighting, restricted access to green spaces, and poor air quality. The findings of this study emphasised the advantages of incorporating natural elements in BOH areas like plants, water features, and natural materials, thus providing valuable insights into successful implementations (Hindley et al., 2020).

These examples give emphasis to the potential benefits of biophilic design in mitigating challenges experienced in workspaces. They can contribute to a deeper understanding of overcoming barriers to incorporate biophilic design within South African private sector hospitals. By employing a similar qualitative approach, the researchers sought to capture in-depth perspectives and experiences of stakeholders, and therefore facilitating a comprehensive understanding of the factors hindering the adoption of biophilic design in hospitals and exploring potential strategies for overcoming these barriers (Legrand, 2020).

Research philosophy and approach

Interpretivism, as the research philosophy, aligns well with the study's objectives and the qualitative methodology. Interpretivism emphasises the importance of understanding social phenomena from the perspective of those experiencing them, facilitating the exploration of subjective interpretations and experiences of stakeholders within the private hospital sector regarding the incorporation of biophilic design. This research philosophy was also employed by (Hindley et al. 2023) in their study on the implementation of biophilic design in the hospitality industry. By utilising interpretivism, they were able to delve into the unique dynamics and subjective understandings of hotel employees regarding the incorporation of biophilic design in back-of-house workspaces. Their study provided valuable insights into the advantages and successful implementations of biophilic design in addressing challenges such as lack of natural light, poor air quality, and restricted access to green spaces. Similarly, the study seeks to comprehend the factors hindering the incorporation of biophilic design in hospitals within the South African private sector. Additionally, the inductive approach supports the development of new and advanced theoretical perspectives, as well as practical recommendations for overcoming barriers.

Sampling

For this research study, the sample (the group of individuals that data was collected from (Ravikiran, 2023)) comprised of designers, architects and green building professionals in South Africa with experience in their respective fields within the country's private healthcare industry. Also forming part of the sample used in the study were the stakeholders of private sector hospitals.

Purposive sampling was beneficial in the study as it allowed the researchers to probe the population to find suitable interviewees. By doing so, the researchers ensured that the data collected originated from reliable sources. Snowball sampling further permitted the existing participants to recommend and recruit additional participants into the study (Simkus, 2023). As such, interviewees were requested to invite candidates within their professional communities who shared the same or similar expertise. The participants consisted of three competent individuals who were designers, architects, and other key stakeholders within the healthcare industry.

Data collection and analysis

Semi-structured interviews incorporating 15 open-ended questions were conducted. By employing this approach, data was collected by the researchers. Interviewees were given the liberty to elaborate on and provide detailed responses to their answers. Furthermore, by implementing semi-structured interviews, the interviewers could ask follow-up questions and request the interviewee to further elaborate on new topics that emerged during the interview. Thematic analysis was applied to gather the interview data and to identify themes and patterns.

Research Results

Comprehension of biophilic design

Defining and comprehending the concept of biophilic design would be the first approach for architects, designers, and hospital stakeholders to pursuing biophilic design incorporation in healthcare environments. The importance of consensus on the comprehension of biophilic design amongst these individuals is that it facilitates effective collaboration and helps to clearly outline common objectives. Consensus also fosters more development, interest, and research into biophilic design. It encourages regulatory compliance, and it assists with developing feasible and measurable outcomes.

Participant 1 mentioned the fact that biophilic design extends beyond simply planting vegetation into the built environment. In their broader perspective, it serves as an *“...architectural feature...”* that is incorporated into the sustainability design of buildings. Therefore, techniques such as introducing vegetation into buildings are sustainable approaches aimed at *“...assisting with the air quality...”* or *“...assisting with energy consumption...”* for example.

Participant 2 proposed the concept of biophilic design by outlining its fundamental purpose which is to *“...rekindle that intrinsic connection that all humans have to nature...”*. They acknowledged how important the need for biophilia is and expounds on the increasing awareness that people are beginning to have on biophilia, and the need to reflect it in our environments.

Despite a vast majority of people that think the concept is just about the plants, biophilic design for Participant 3 is much broader. It is about the connection between the end users – the humans – and the natural environment through elements and techniques such as *“...natural lighting, enhanced views of the natural environment, incorporating plants, and even the different textures that one brings into the space...”*.

The demand for biophilic design

The incorporation of biophilic design into healthcare spaces and the built environment is garnering an increasing amount of attention amongst architects, interior designers, and project stakeholders, and it is prevalent in the significant shift within the built environment towards the incorporation of biophilia. Participant 2 acknowledged that; *“...there is starting to be a lot more focus (by architects, designers and stakeholders) on local, acting locally...”*. This shift can be attributed to various factors, such as the amplified focus on sustainability, consumer preferences, and the abundance of research findings pertaining to the benefits of biophilic design incorporation. Participant 2 confirmed this by mentioning; *“...there is a lot of data available...”*. These benefits range from enhanced aesthetics and patient well-being to the increased productivity and reduced stress levels of healthcare professionals.

Participant 1 discussed the broad benefits of biophilic design, including environmental appeal, cooling effects on buildings, and market appeal to tenants and buyers. They emphasised how biophilic design can have a positive impact on the whole neighbourhood and serve development projects. *“So, I think there’s wellness is a benefit from an energy point of view. There’s a benefit from a broad environmental point of view. And also, there’s a benefit from a market point of view”*. Through this they outlined the potential environmental and economic benefits of biophilic design in healthcare facilities. It suggested that such design can enhance the appeal of hospitals to tenants and buyers, which is relevant to our study on the private sector.

Participant 2 shared their personal experiences with nature and how it has a grounding and therapeutic effect on individuals. They also discussed the historical issue of *“sick building syndrome”* and the importance of a connection to the natural environment in building design. *“So, I remember this from architecture school, studying kind of modernism and its brutalist architecture, you know, sort of early modernist, in sort of the post war era when, high rise buildings really skyrocketed in the big cities... People were literally getting sick from buildings, buildings were making people sick, and for no apparent reason. ... simple things like that can have such a profound impact on people’s lives”*. It is clear through the elaboration provided by Participant 2, that biophilia has enormous benefits regarding the psychological and overall well-being of patients and staff alike.

Participant 3 continued to elaborate on the benefits provided by the incorporation of biophilic design. They listed various benefits of biophilic design, including reduced anxiety, improved sleep quality, better indoor air quality, faster recovery rates, a stronger immune system, reduced stress levels, and pain reduction. They continued by stating that research supports these findings. *"There's a lot of research to back all of this up. And the findings are always clear... where patients have access to green elements, plants, or outdoor areas. They do tend to heal a lot faster"*.

Specialist innovation within the field

Incorporating biophilia into the built environment is an extremely complicated endeavour, and increasing the number of specialists is essential to the successful incorporation of biophilia. Due to the increase in the demand for biophilic design, an increased number of specialists may be drawn to the field, potentially resulting in, and stimulating innovation in design concepts, as elaborated on by Participant 1; *"...the more demand there is, the more specialists you'll get in the market..."*. The creation of innovative technologies and equipment tailored to the incorporation of biophilic design, such as advanced indoor plant irrigation systems or lighting solutions that mimic natural light, is of utmost importance to ensure its success.

Participant 1 continued as follows: *"So the chance that it's going to fail is very much reduced"*. The combination of attracting more specialists into the field, and developing sophisticated equipment, will drastically reduce the likelihood of failure pertaining to the incorporation of biophilic design.

Participant 1 discussed the complexity of biophilic design, highlighting the need for specialised consultants, technical skills, and extensive planning for irrigation, drainage, and maintenance. They emphasise the challenges associated with the practical aspects of biophilic design, such as water management and ongoing maintenance. *"You've got to bring in systems to irrigate, which are more complex... It's a major feat for them (architects) to achieve that there's a building here in Rivonia... Your average architect, an interior designer is not going to give you a solution that works well"*. This underscores the technical challenges and costs associated with implementing biophilic design. It sheds light on the need for a multidisciplinary approach and the potential hurdles related to design, coordination, and maintenance.

Development of maintenance services

Notwithstanding the increase in demand for biophilic design, the practical challenges of maintaining biophilia within the built environment is a massive concern among project stakeholders and developers, hindering its incorporation, as elaborated on by Participant 1; *"...for most hospitals, the cost of maintenance is the big driver..."*. *"They have got to work harder for them to exist."* The cost of maintenance, efforts to sustain biophilic designs, and ongoing maintenance seem to be major challenges. Maintenance services encompass a wide variety of aspects, from routine plant care to the repair of irrigation or ventilation issues that may arise. Participant 3 discussed the importance of detailed maintenance plans and the submission thereof as part of the design process. *"What you would also need to submit as part of your submission process is actually your maintenance plan"*.

These responses highlighted several factors hindering the incorporation of biophilic design into South African private sector hospitals, which included: The need for specialised consultants and technical skills; the cost implications of using context-specific materials; the importance of thorough maintenance planning and water management.

Financial implications

A further obstacle that hinders the incorporation of biophilic design are the financial implications it has on project execution. Participant 3 began by saying; *"...plants are very expensive..."*. If the integration of biophilia was considered by stakeholders, the results of feasibility studies usually persuade stakeholders to decide otherwise. Participant 2 stated that; *"...feasibilities (studies) are where a lot of these things often gets thrown out of projects..."*. Participant 2 continued; *"...every single project has millions of barriers that it needs to overcome, cost being a huge one of that. And with massive rising cost it is getting worst and worst and worst and worst"*. Short-term cost constraints overshadow the long-term advantages that biophilic design can bring to a healthcare setting, as conveyed by Participant

3; *“...it could seem that it is a very big upfront cost, with them (stakeholders and developers) not having the long-term benefits...”*.

Contrasting approaches to healthcare design

Considering the contrasting approaches between different countries, such as Australia and South Africa, it becomes prevalent that the priorities of the South African healthcare sector do not lie with design improvements. Australia's strong focus on green design and sustainability in healthcare environments reflects a cultural emphasis on environmental responsibility. This fact was brought to light by Participant 1; *“...Now Australia's very focused on green design and they spend a lot in their hospitals, especially in Victoria... they (Australians) don't really watch spreadsheets as carefully, they rather focus on what is the quality of the place (Hospital)”*. Compared to the South African healthcare sector, which is categorised as sterile and bland, suggests a lack of the broader environmental and well-being aspects of healthcare facility design. Participant 1 highlighted this through; *“...the healthcare environment in South Africa and they are certainly not interested in biophilic design...”*. Participant 2 confirmed this and continued; *“...it's typically grey vinyl with curved edges and dropping ceilings with those horrible bright fluorescent lights...that's not conducive to healing...”*.

Importance of education

Education pertaining to the benefits of biophilic design in healthcare environments is crucial to its implementation. However, it is also one of the main factors that hinder its incorporation. The importance of education was first outlined by Participant 2; *“...we as building professionals need to educate and bring people on board”*. Participant 3 also proposed education as a solution to various barriers; *“...with biophilia, it really is education. That will be the biggest thing”*. There is a substantial gap between the knowledge pertaining to and comprehensively understanding biophilic design within the construction and healthcare industries. Scepticism, misconceptions, and a lack of awareness often serve as significant barriers to its adoption.

A lack of knowledge and understanding is also one of the main reasons why contrasting viewpoints are encountered, as elaborated on by Participant 3; *“...were there will be pushback (regarding the value or necessity of biophilic design), is lack of knowledge”*. Developers, designers, and stakeholders do not comprehensively grasp the potential benefits that biophilic design can offer to patients and staff members. This knowledge gap is crucial barrier that needs to be overcome.

The importance of biophilic design frameworks

Participant 2 was involved in the Green School project which had biophilic design specifications and requirements and complied with living building standards. *“So, we designed that building and there were biophilic requirements, a component of it was biophilic design. It was the living building standards that the building had to comply to, and one component of that was biophilic design”*.

To develop a biophilic design framework that could be implemented without variation in any region around the world will not be feasible. Participant 2 explained the need for place-based frameworks; *“...when we talk about place-based biophilic design, it just needs a framework (on how to incorporate biophilic design in different regions), just saying the be mindful of these things...”*. Participant 3 later elaborated on the fact that all frameworks will not be applicable to any region; *“...some of them can be adjusted and across the world, and some of them, what we would call, don't travel well. So, a tool that was made for the European conditions is unlikely to have the same positive impact and/or elements required for the African context.”* The need for customisability and adaptability illustrates that the incorporation of biophilic design is a deliberate and strategic endeavour, requiring a wealth of knowledge and an in-depth understanding of what is required.

Participant 2 conversed about the specific context of biophilic design in different geographic locations, such as the differences between South Africa and Bali. They mention that biophilic architecture differs based on the climate and the materials available in the environment. *“It's a tropical climate (Bali), so they don't have to deal with the extreme weather conditions that we (South Africans) have to deal with”*.

Green building rating frameworks or tools

Green Star rating tool and the LEED's rating tool are among several green building rating tools that have been developed around the world. These tools support the integration of biophilia to some degree, which can be seen as a step in the right direction. Participant 3 brought this fact into the light through stating; *"...there are many Green Building Rating Tools, and most of them incorporate biophilic design to some extent"*. They mention elements such as natural light, external views, and indoor plants. However, these tools focus more on sustainability in general and the necessity thereof, and not so much directly on the incorporation of biophilic design. This was confirmed by Participant 2; *"...there are a lot of Green Star Ratings and LEED's ratings in buildings which have sustainability as their objective..."*

Although green building rating frameworks or tools touch on biophilic design, they are not specifically designed for the incorporation of biophilic design. A tailor-made framework must be developed to aid stakeholders and designers on how biophilic design should be effectively incorporated to ensure its success, with adaptability and customisability at the core of such framework.

Hygiene concerns regarding biophilic design integration

A great concern lies among healthcare stakeholders regarding hygiene within hospitals and the effect the incorporation of biophilic design will have. Hospitals are inherently infectious environments, and the concern arises from the incorporation of biophilic design which might exacerbate this issue. This was initially raised by Participant 1; *"...but you know the Spital environments are actually very infectious, it's not good for you to stay in hospital for very long"*. There is a delicate balance between developing a natural and restorative environment through the integration of biophilic systems and adhering to the strict hygiene protocols of hospitals, which greatly hinders the incorporation thereof. However, Participant 3 outlined that; *"...there's more that supports incorporating biophilia in healthcare design then there would be linked to hygiene"*. Participant 2 proposed; *"...you can still create a contained space..."*.

Hospital spaces already have sophisticated infection control protocols and hygiene maintenance systems in place, as conveyed by Participant 3; *"...Hospitals would have a very strict policy...they (hospitals) already have a very strong system of ensuring that hygiene is kept at the forefront of all the cleaning that is done..."*. Rigorous cleaning, sterilisation and disinfection practices are executed intermittently on a daily basis. Additionally, hospitals have more pressing concerns pertaining to hygiene that must be diligently controlled. These concerns include the quality of air circulation, and systematic infection control in waiting areas with ill patients. As Participant 3 stated; *"...the rules and regulations they (private sector hospitals) have around hygiene is of such a standard that the plants are not the issue that brings in hygiene or infection control issues..."*. Thus, the incorporation of biophilic design into healthcare environments should not be seen as a direct challenge to these practices and protocols, as the need for hygiene can be accomplished alongside biophilic design, as elaborated on by Participant 3; *"...the element of adding plants into that should not contribute to any negative aspects around infection control"*.

Participant 3 was involved in the development of Cintocare, the first Green Star-certified hospital in South Africa, which embraced a significant focus on biophilic elements. *"So Cintocare is the first and I'm not sure, but I do think the only Green Star certified hospital in the country and in Africa. And so, for that project, there was quite a significant focus on bringing biophilic elements into the hospital as much as could be allowed in terms of infection control regulations"*.

Biophilic design can positively impact patient wellness, as demonstrated in the case of Linksfield Park Clinic (Participant 1). Compliance with specific standards, such as the Living Building Standards, can be a factor in incorporating biophilic design, as seen in the Green School project (Participant 2). The successful incorporation of biophilic design is feasible, even in healthcare facilities with stringent regulations, such as the Green Star-certified Cintocare hospital (Participant 3).

Several additional factors that hinder the incorporation of biophilic design into South African private sector hospitals were outlined and included: The challenge of maintenance and the resources required to sustain biophilic designs; the impact of infection control regulations on the placement of plants and biophilic elements in healthcare facilities; and the influence of local context, climate, and materials on the implementation of biophilic architecture.

Elevating patient wellness through innovative biophilic design

Participant 1 mentioned their involvement in Linksfield Park Clinic, where biophilic elements, such as gardens and terracing, were an integral part of the design to enhance patient wellness. *“...the interesting thing there is that the terracing was an integral part of the design to really contribute to the wellness of patients”.*

Discussion According to Objectives

Assessing awareness among stakeholders

The findings indicate an increase in awareness among project designers, developers, and stakeholders. The growing emphasis on sustainable development and the availability of research findings outlining the benefits of biophilia in buildings both have a direct impact on this increase. Despite the increased awareness and the recognised benefits, a wide variety of factors extremely hinders the incorporation of biophilic elements in healthcare spaces.

Barriers to the Implementation of biophilic design

Several factors hinder the sustainable implantation of biophilic design in hospital spaces. These challenges include the requirement for specialised knowledge and expertise, maintenance issues, financial constraints, insufficient guidance and frameworks pertaining to the incorporation of biophilia, lack of education, and how such incorporation affect hygiene concerns in hospitals. Moreover, the requirement of infection control protocols and building codes further restricts the integration of biophilic elements. These obstacles must first be addressed before the widespread adoption of biophilic design can take place.

The effects of biophilic design on patients and staff

The study highlights the impact of that biophilic design could possibly have on patients and staff, suggesting that such design can foster enhanced wellness, reduce stress, and accelerate the recovery process. Furthermore, finding also points to potential benefits such as strengthening the immune systems of patients and reducing pain perception among patients. there is evidence to suggest that biophilic design may strengthen the immune system and reduce pain perception among patients.

Contributing to solutions

To address the various obstacles hindering the successful implementation of biophilic design in healthcare spaces, innovation within the field is indispensable. Firstly, developing maintenance services is crucial to maintain biophilic elements successfully. To bridge the existing knowledge gap, educational programs should be developed by green building regulatory bodies. Furthermore, to address hygiene concerns and infection control, enclosed areas can be created, or self-cleaning materials can be utilised. Additionally, developing design frameworks specially tailored for the incorporation of biophilia is important to guide developers in their pursuit of its implementation.

Conclusion

The research has potentially shown a considerable increase among designers, architects, and developers regarding the implementation of biophilic design. This growing awareness is largely due to the rising focus on sustainability and the abundance of research outlining the perceived benefits of biophilic design. However, the paper has possibly identified significant challenges to implementing biophilic design in healthcare environments. These challenges include financial costs, maintenance issues, the need for specialised knowledge within the field, a lack of education pertaining to biophilic design, limited guidance from green building guidelines, infection control and hygiene. Despite these challenges, the advantages biophilia offers within healthcare spaces outweigh the drawbacks.

Recommendations

With the prominent small sample size, a study with a larger sample size could greatly contribute to further findings. A case study on a hospital that has successfully integrated vegetation and biophilia could also provide valuable insights for future projects.

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From Departure to Development: Exploring and Reducing Migration Drivers Among South African Quantity Surveyors

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Abstract

This paper aims to explore and address the factors driving the emigration of South African quantity surveyors, with the goal of developing strategies to mitigate these challenges and retain skilled professionals within the country. Utilising an interpretivist research paradigm, the study employed a qualitative methodology through narrative inquiry, conducting semi-structured interviews with South African quantity surveyors who have emigrated within the last ten years. Snowball sampling, a form of non-probability sampling, was utilised to recruit a total of 15 participants. The study identified key factors driving the emigration of South African quantity surveyors, including inadequate remuneration, limited career advancement, and political instability. Participants highlighted the significant impact of South Africa's political and professional landscape, with crime rates and poor pay further influencing their decisions. To address these issues, suggestions were made for policy reforms and improved professional development programs. These strategies could help reduce emigration and support the retention of skilled professionals, offering valuable insights for developing initiatives to combat brain drain in the quantity surveying profession. While the study identifies potential strategies to reduce these push factors, it also acknowledges limitations, including the challenges of scaling these strategies for broader applications. The practical implications of this research are significant for policymakers and professional organisations seeking to retain talent within the South African quantity surveying profession. By addressing these emigration drivers, the study offers actionable insights to counteract brain drain and enhance the sustainability of the profession in South Africa. This research fills a gap in the existing literature by providing a focused analysis of the emigration dynamics within this critical professional group and proposing tailored strategies for mitigation.

Keywords: Emigration, Push factors, South Africa, Quantity Surveyors.

Introduction

"Perhaps home is not a place but simply an irrevocable condition"(Baldwin, 1955:92). Baldwin's quote expresses the idea that leaving home is not just about a physical departure but also a psychological shift. This encapsulate the complex dilemma faced by professionals in South Africa, particularly quantity surveyors, who are increasingly choosing to emigrate. This trend raises concerns not just for the individuals involved but for the broader sustainability of the profession in the country. Emigration, particularly of skilled professionals, is not merely a personal choice but a reflection of broader systemic issues within a country (Adeyemi, Joel, Ebenezer & Attah, 2018:67).

Emigration, especially among skilled professionals like quantity surveyors, has significant implications for South Africa's economic and professional landscape. The phenomenon of "brain drain" has been extensively studied, revealing its detrimental impact on the countries that lose their most qualified professionals (Adeyemi *et al.*, 2018; Chand, 2019). South Africa, like many developing nations, suffers from a persistent outflow of skilled labour due to push factors such as inadequate remuneration, political instability, and limited career advancement opportunities (Fatima Rasool & Botha, 2011; Labonté, Sanders, Mathole, Crush, Chikanda *et al.*, 2015). Despite numerous studies highlighting the causes and consequences of professional emigration, there is a noticeable gap in the literature specifically addressing the migration of South African quantity surveyors (Popogbe & Adeosun, 2022). Previous research has predominantly focused on broader categories of professionals, often overlooking the unique challenges faced by this specific group. Moreover, existing studies have been limited in their

scope, often failing to propose actionable strategies to mitigate the exodus of skilled professionals. On the other hand, while much has been discussed about brain drain in general, the specific experiences and motivations of South African quantity surveyors remain underexplored. The lack of focused research on this professional group presents a critical gap in the literature. Without a detailed understanding of the unique push factors affecting quantity surveyors, any attempts to address their emigration will likely fall short. The aim is to fill that gap by offering a comprehensive analysis of the factors driving their emigration and proposing targeted strategies to mitigate these issues. If this trend is not addressed, South Africa risks further depletion of its skilled workforce, leading to long-term negative consequences for its construction and built environment sectors. This research aims to explore and address the factors driving the emigration of South African quantity surveyors, with the goal of developing strategies to mitigate these challenges and retain skilled professionals within the country.

The study's aims led the researcher to the following objectives: identify the key financial, social, professional, and political factors influencing the emigration of quantity surveyors, analyse the impact of these factors on the professional landscape in South Africa and propose actionable strategies to reduce the push factors and retain skilled professionals within the country. The message to the reader is clear: addressing the emigration of quantity surveyors is not just a professional necessity but a national imperative. By understanding and mitigating the factors driving their emigration, South Africa can safeguard the future of its construction industry and ensure the continued availability of skilled professionals. The paper will begin by reviewing the relevant literature on professional migration and brain drain, followed by a detailed analysis of the push factors specific to South African quantity surveyors. The research methodology will then be discussed, highlighting the use of qualitative methods to gather in-depth insights from emigrated professionals. The findings will be presented in relation to the identified push factors, leading to a discussion on the proposed strategies for mitigating emigration. Finally, the paper will conclude with practical recommendations for policymakers and professional organizations, emphasizing the importance of retaining skilled professionals within the country.

Literature Review

Defining migration

Migration is a significant phenomenon that involves the movement of individuals across regions or countries for various reasons, including economic, social, political, and financial factors. According to Akanbi (2017:683), migration is motivated by these multifaceted reasons, with individuals often seeking to establish permanent or semi-permanent residency in new location Khosa and Kalitanyi (2015:134). Migration can be categorized into internal migration, which involves movement within a country, and international migration, where individuals cross national borders (Khosa & Kalitanyi, 2015:134). Further distinctions include interregional, intracontinental, and intercontinental migration (Rwodzi, 2011:18). Understanding the distinctions between these types of migration is crucial for contextualizing the broader phenomenon of brain drain, particularly in the context of highly skilled professionals. Brain drain, or human capital flight, refers to the emigration of educated and skilled individuals from developing countries to more developed regions, driven by the pursuit of better wages, career prospects, and living conditions (Panagiotakopoulos, 2020:207; Popogbe & Adeosun, 2022:6). This movement can have significant implications for both the source and destination countries, as it reduces the availability of trained professionals and potentially lowers the quality of services in the countries left behind (Adeyemi *et al.*, 2018:69; Bhardwaj & Sharma, 2022:6; Popogbe & Adeosun, 2022:7). Brain drain can result in cultural capital loss and socio-economic imbalances, in addition to talent transfer (Radonjić & Bobić, 2021). The following sections will explore the specific factors driving this migration, particularly within the South African context.

Push factors

Migration is a multifaceted and complex phenomenon influenced by a variety of factors, including both push and pull factors. In the context of international migration, push factors are particularly significant, as they originate within the migrant's home country and are typically viewed as negative forces that push individuals to leave (F. Rasool, Botha & Bisschoff, 2013:12). These push factors are not usually isolated but rather represent a complex interplay of various forces that collectively drive professionals to seek opportunities in other countries.

Financial push factors

Financial challenges are a predominant factor driving the emigration of professionals from South Africa. Research by Popogbe and Adeosun (2022:6), Rasool *et al.* (2013:11-13), and Hashish and Ashour (2020:707) identify poor salaries, inadequate compensation for stress, and high living costs as critical economic pressures that influence professionals to seek opportunities abroad. Additional studies highlight the role of inflation and currency fluctuations in exacerbating these financial difficulties, making it challenging for professionals to maintain financial stability in South Africa (Dube & Rukema, 2013; Schlechter, Faught & Bussin, 2014:2). These financial pressures create a situation where professionals feel undervalued and overworked, leading them to consider emigration as a viable option for improving their economic well-being (Kanayo, Anjofui & Stiegler, 2019:232). While some studies suggest that financial issues are the primary cause of emigration, others argue that they are part of a broader set of factors that collectively drive this decision (Shumba & Mawere, 2012; Hashish & Ashour, 2020:707-708). This complexity suggests that financial factors alone may not fully explain the emigration phenomenon, but they certainly contribute significantly to it. The discussion will now turn to social factors, which also play a critical role in influencing professionals to leave South Africa.

Social push factors

Social conditions, including safety concerns and job satisfaction, are significant contributors to the decision to emigrate. Studies by Hashish and Ashour (2020:708), Asadi, Ahmadi, Nejat, Akbari Sari, Garavand *et al.* (2018:5) and Dube and Rukema (2013:68) indicate that unsafe working conditions, low job satisfaction, and high crime rates are key social factors that push professionals to seek better living and working environments elsewhere. The persistence of low living standards in South Africa, compounded by high crime rates, further exacerbates the desire to emigrate (Marchetti-Mercer, 2012:243; F. Rasool *et al.*, 2013:13). These social challenges undermine the overall quality of life for professionals, leading to dissatisfaction with both their work environment and their personal safety (F. Rasool *et al.*, 2013:13; Panagiotakopoulos, 2020:210). The impact of these social push factors is particularly pronounced in countries like South Africa, where the economic and political environments are already unstable. Professionals facing such conditions may view emigration as not just an option but a necessity for achieving a higher standard of living and personal security. Political factors, which will be discussed next, often intersect with these social issues, further influencing the decision to emigrate.

Political push factors

Political instability and corruption are critical factors that drive the emigration of professionals from South Africa. Political instability, poor governance, and corruption are frequently cited by professionals as reasons for leaving their home countries (Rasool *et al.*, 2013:14; Chand, 2019:9; Hashish & Ashour, 2020:714; Popogbe & Adeosun, 2022:6). The degradation of infrastructure and the inefficiency in resource distribution due to political corruption further exacerbate the challenges faced by professionals (Molepo, 2018:796). Additionally, affirmative action policies like the Broad-Based Black Economic Empowerment (BBBEE) can limit career opportunities for certain groups, contributing to the brain drain (Rasool *et al.*, 2013:15; Mlambo & Adetiba, 2019:7). The intersection of political and economic challenges creates an environment where professionals feel undervalued and unsupported by their government. The perceived lack of opportunities, coupled with systemic corruption, undermines trust in the political system, prompting professionals to seek stability and recognition in other countries (Rasool *et al.*, 2013:19). While some may argue that affirmative action policies are necessary for redressing historical inequalities, the unintended consequences of these policies on professional emigration cannot be ignored. The next section will explore how professional factors, such as career prospects, further influence the decision to emigrate.

Professional push factors

Limited career opportunities and high unemployment rates are significant professional factors driving emigration. Insufficient career advancement opportunities and high unemployment rates are commonly cited reasons for emigration among South African professionals (F. Rasool *et al.*, 2013:13, 15; Khosa & Kalitanyi, 2015:136; Wanniarachchi, Kumara Jayakody & Jayawardana, 2022:1491). The lack of career progression, combined with the country's slow economic growth, compels many professionals to seek opportunities abroad (Mlambo & Adetiba, 2019:3). South Africa's high unemployment rate, one

of the highest in the world, further exacerbates this issue (Fatima Rasool & Botha, 2011:10; Popogbe & Adeosun, 2022:6). The professional landscape in South Africa is characterized by limited opportunities for growth and development, making it difficult for professionals to advance in their careers. This lack of prospects and economic challenges drive skilled professionals to emigrate in search of better opportunities. The high unemployment rate also means that even those employed may feel insecure in their positions, further motivating them to leave. Having examined the various push factors, the following section will discuss potential strategies for mitigating these factors to reduce professional emigration.

Strategies to reduce push factors

To retain skilled professionals, South Africa must implement strategies that address the financial, social, political, and professional factors driving emigration. One potential strategy involves improving financial incentives by providing government support to organizations, enabling them to offer competitive salaries and comprehensive training programs (Akinto, 2021). Currently, the Skills Development Act 97 of 1998 is useful for training but does not address the need for wage increases (Africa, 1998). In terms of social issues, the National Crime Prevention Strategy (NCPS) is based on the principle of separate examinations for each type of crime, with the aim to shift from reactive crime control to proactive crime prevention, although further efforts are required to make South Africa safer (Africa, 1996). Politically, revising affirmative action policies like BBBEE and eradicating corruption could significantly reduce the push factors driving emigration (Rasool *et al.*, 2013; Roudgar & Richards, 2015). Finally, initiatives such as the Jobs Summit, Youth Employment Service, and Employment Tax Incentive aim to reduce unemployment and create job opportunities, although the effectiveness of these measures remains limited given the persistently high unemployment rate (Africa, 2023; SA, 2023). If implemented effectively, these strategies could address the underlying issues that drive professionals to emigrate. By improving financial stability, enhancing safety, fostering political stability, and creating more professional opportunities, South Africa could mitigate the factors that contribute to brain drain. However, the success of these strategies will depend on their comprehensive implementation and the willingness of policymakers to address the root causes of emigration. The effectiveness of these strategies will ultimately determine whether South Africa can retain its skilled professionals and reduce the negative impacts of brain drain.

Research Methodology

This study employed a qualitative research methodology to explore the complex factors driving the emigration of South African quantity surveyors. The choice of a qualitative approach was made due to its capacity to capture the complexity and depth of participants' experiences and perceptions. This methodology allows for a comprehensive understanding of the nuanced social, economic, and professional factors influencing emigration decisions, which would be difficult to quantify using quantitative methods.

Qualitative instrument

Semi-structured interviews were utilized as the primary data collection technique to gather detailed and context-rich data. Semi-structured interviews were selected because they provide a structured framework while allowing flexibility to explore participants' responses in greater depth. The interviews were only conducted via online platforms due to the geographical location and availability of the participants. Each interview lasted between 30 minutes and one hour and 20 minutes, providing sufficient time for in-depth discussion, which can be seen in Table 1 below. The interview guide was carefully developed to align with the research objectives, focusing on key themes such as financial pressures, social conditions, political factors, and professional experiences.

The interview guide was developed through a rigorous process to ensure its validity and alignment with the research objectives. The questions were formulated based on a thorough review of existing literature on professional migration and brain drain.

Table 1: Participant Information

Population and sampling

The study focused on South African quantity surveyors who have studied in South Africa and emigrated within the past ten years. This population was selected because their recent experiences provide valuable insights into the current factors driving emigration. Participants varied in age, gender, years of professional experience, and emigration destinations, which included places such as Australia, New Zealand, the United Kingdom, Ireland and the United Arab Emirates (Dubai and Qatar). This can be seen in Table 1 below.

Table 1: Participant demographics

Participant Number	Race	Gender	Emigration Date	Where immigrated to	Time spent on interview
One	White	Male	2018	Dubai	36m 32s
Two	Black	Female	2018	Dubai	47m 29s
Three	White	Female	2017	Australia	1h 01m 12s
Four	White	Male	2020	New Zealand	45m 22s
Five	White	Female	2016	Dubai	1h 03m 24s
Six	White	Female	2016	Australia	55m 40s
Seven	White	Male	2022	Ireland	1h 06m 21s
Eight	White	Male	2023	New Zealand	40m 29s
Nine	White	Female	2023	Ireland	1h 20m 03s
Ten	White	Male	2021	Qatar	30m 03s
Eleven	Black	Male	2015	United Kingdom	57m 38s
Twelve	Black	Female	2022	Ireland	57m 49s
Thirteen	Black	Male	2023	Ireland	1h 05m 24s
Fourteen	Black	Male	2018	New Zealand	1h 16m 57s
Fifteen	Black	Male	2017	United Kingdom	1h 10m 13s

Snowball sampling technique was employed to recruit participants for this study. This method was chosen due to the specialized nature of the target population, which is relatively small and dispersed across different countries. The process began by identifying an initial group of emigrated quantity surveyors through professional networks and social media platforms. These initial participants were then asked to refer others who met the study's criteria. While snowball sampling is effective for accessing hard-to-reach populations, efforts were made to ensure diversity within the sample to reduce potential biases.

Data analysis

The data obtained from the interviews were analysed using thematic analysis, which is well-suited for identifying and interpreting patterns within qualitative data. The analysis followed the six-phase process established by Braun and Clarke (2006:87). Initially, the researcher familiarized themselves with the data by thoroughly reading the interview transcripts multiple times. This was followed by generating initial codes highlighting significant data points. These codes were then organized into potential themes, which were reviewed and refined to ensure they accurately represented the data. The final themes concerning the research questions and existing literature were analysed, ensuring that the findings were robust and grounded in the participants' experiences.

Research Results

Figure 1 below depicts how the use of thematic analysis yielded five themes from the participants.



Figure 1: Coding tree for research results

Theme 1: Financial push factors

The analysis revealed that financial pressures are a significant driver of emigration among South African quantity surveyors. Participants consistently reported dissatisfaction with their compensation, highlighting inadequate salaries, a lack of benefits, and poor remuneration for the level of stress and responsibility associated with their roles. These findings align with previous studies that have identified low pay as a critical push factor in professional emigration (F. Rasool *et al.*, 2013:14; Popogbe & Adeosun, 2022:6). For example, one participant stated, "The salary does not match the workload or the cost of living. It is simply not sustainable." This sentiment was echoed by several others, who also pointed to the high cost of living in South Africa, exacerbated by inflation and currency fluctuations, as key factors in their decision to seek better opportunities abroad. Another participant reinforced this sentiment, expressing that they had reached "a break-even point," which they believed should not have been the case. These financial concerns mirror the findings of Dube and Rukema (2013:67) and F. Rasool *et al.* (2013:14), who noted that economic instability and high living costs are major contributors to the brain drain phenomenon. These results are consistent with the broader literature on brain drain, which often cites financial dissatisfaction as a primary motivator for emigration. However, this study

adds nuance by detailing how specific economic challenges, such as inflation and currency devaluation, intensify the push to leave South Africa.

Theme 2: Social push factors

Participants also highlighted social factors as significant influences on their decision to emigrate. Key issues included unsafe working conditions, high crime rates, low job satisfaction and South Africa's standard of living. One participant described the working environment as "stressful and dangerous," citing high crime rates, receiving death threats on-site and the lack of basic security as daily concerns. Another participant noted, "The stress of living with constant fear for personal safety was overwhelming," especially after their "wife got robbed whilst doing her morning exercise". These findings support the work of Rasool *et al.* (2013:13) and Marchetti-Mercer (2012:243), who emphasized the impact of crime and safety concerns on emigration decisions. Participants felt that South Africa's standard of living has deteriorated over time, linking it to financial issues, poor remuneration and high crime rates. The low job satisfaction reported by participants was often linked to poor working conditions, including inadequate resources and support, leading to frustration and burnout. This aligns with previous studies that have identified poor workplace conditions as significant factors in professional dissatisfaction and emigration (Asadi *et al.*, 2018:5; Hashish & Ashour, 2020:708). While the literature generally agrees on the importance of social factors in driving emigration, this study contributes additional insights into how safety concerns, in particular, play a critical role for South African quantity surveyors. The emphasis on crime and personal safety as push factors is particularly noteworthy, given the high crime rates in South Africa and their profound impact on professionals' quality of life.

Theme 3: Political push factors

Political instability and corruption emerged as powerful push factors in the participants' narratives. Many expressed deep frustration with the political climate in South Africa, citing corruption and inefficient governance as major reasons for leaving. One participant remarked, "The level of corruption is unbearable. There is no trust in the system, and it feels like the country is falling apart." The degradation of infrastructure, attributed to poor governance, and affirmative action were other common concerns. Participants described how unreliable infrastructure, particularly in energy and transport, hindered their professional activities and contributed to their decision to emigrate. They also expressed frustration over restricted career opportunities due to affirmative action policies like BBBEE. One participant remarked, "I hated that my competence and capabilities would be questioned because I'm Black.". These issues are consistent with Chand (2019:9), Mlambo and Adetiba (2019:7) and Molepo (2018:796), who also identified political instability and poor infrastructure as significant factors in professional emigration. The results corroborate existing literature on the negative impact of political instability, corruption and affirmative action on emigration decisions. However, this study underscores the specific frustrations with governance, infrastructure degradation and BBBEE, highlighting the direct impact these issues have on the daily lives and career prospects of quantity surveyors.

Theme 4: Professional push factors

Limited career opportunities, high unemployment rates and a lack of professional advancement were also identified as key drivers of emigration. Participants reported feeling "trapped" in their professional roles, with few opportunities for advancement or career growth. One participant mentioned, "There is no room for progression. You hit a ceiling very quickly, and the only way up is out." The study found that the high unemployment rate in South Africa exacerbated these concerns, as even those employed felt insecure in their positions. This finding aligns with research by Wanniarachchi *et al.* (2022:1491) and Popogbe and Adeosun (2022:6), who noted that professionals often emigrate when they perceive limited career prospects and job security in their home country. These findings are consistent with the broader literature on professional migration, which often cites limited career opportunities as a key factor in emigration decisions. This study adds to the understanding by emphasising the perceived lack of career progression and the impact of high unemployment on professional insecurity, which are particularly acute in the South African context.

Theme 5: Strategies to reduce push factors

The participants shared a variety of perspectives and suggestions on how to address the push factors causing quantity surveyors to emigrate from South Africa. Some focused on improving working conditions within South African organisations, suggesting that better salaries and bonuses, leave policies, and attention to mental health could deter quantity surveyors from leaving. One participant mentioned, "Ireland seems to take care of their employees a lot more, the bonuses and you get more leave. It makes people want to be there". This supports Akinto (2021:447) argument that this issue needs to be addressed and rectified with the aid of South Africa's government. South Africa currently makes use of the Skills Development Act 97 of 1998, which aids organisations in training their employees but does not help them provide improved working conditions (Africa, 1998). Safety concerns were also highlighted as a factor that needs improvement to reduce emigration. The National Crime Prevention Strategy has been developed to shift emphasis from reactive 'crime control' to proactive 'crime prevention', with the intent to decrease South Africa's crime and violence levels (Africa, 1996). Even with this development, South Africa's levels are still increasing as stipulated by Stats SA (Africa, 2022). Participants suggested that South Africa's government needs to "look at and refine" affirmative action policies such as BBBEE, as the country is not where it was in 1994. This strategy was also suggested by F. Rasool et al. (2013:19) to see where these policies can be improved to help ensure that people are chosen based on both their history of discrimination and their actual skills. There was a range of opinions from the participants on graduate programs, with some participants believing they could help, while others are sceptical, particularly about potential low salaries for graduates in these programs. One participant mentioned that graduate programs "would attract and retain talented quantity surveyors and assist them to grow and develop their skills". The government has created initiatives such as the Employment Tax Incentive which helps organisations with the cost of hiring young people by decreasing the amount of Pay-As-You-Earn tax paid while leaving their salaries unaffected (SARS, 2022). It is, however, evident from the participant's responses that this is not being implemented adequately within the quantity surveying profession. Some participants thought more learnership programs could help while others suggested that international companies should open offices in South Africa or partner with local firms to create job opportunities. Others proposed that universities should incorporate work experience into the curriculum, potentially partnering with firms to offer practical opportunities for students, aiming to increase graduates' employability.

Conclusion

This study explored the factors driving the emigration of South African quantity surveyors and proposed strategies for mitigating this brain drain. The findings of the study provide clear answers to the research objectives, offering insights into the financial, social, political, and professional push factors that influence the decision to emigrate. These conclusions are synthesized to present a cohesive understanding of the emigration phenomenon within this professional group.

Financial Pressures: The study found that inadequate salaries, high living costs, and economic instability are significant financial push factors that compel quantity surveyors to seek better opportunities abroad. These findings confirm the existing literature on the role of financial dissatisfaction in professional emigration and highlight the need for more competitive remuneration strategies within South Africa.

Social Conditions: Critical social push factors were identified as unsafe working environments, high crime rates, and low job satisfaction. These conditions create a sense of insecurity and dissatisfaction among professionals, contributing to their decision to emigrate. The study adds to the literature by emphasizing the impact of crime and safety concerns, particularly acute in South Africa.

Political Instability, corruption and affirmative action: Political factors, including corruption, inefficient governance and BBBEE, were found to significantly influence emigration decisions. The degradation of infrastructure and lack of trust in the political system exacerbate the desire to leave. This study supports existing research on the negative impact of political instability on professional retention, while also highlighting the specific frustrations faced by South African quantity surveyors.

Professional Opportunities: The lack of career advancement opportunities and high unemployment rates were significant professional push factors identified in the study. The findings suggest that the limited career progression available in South Africa drives professionals to seek growth opportunities

elsewhere. This aligns with the broader literature on professional migration and underscores the need for improved career development frameworks within the country.

Strategies: Several strategies were identified that could mitigate the push factors driving South African quantity surveyors to consider emigration. Key among these, is the expansion of graduate programs, internships and learnerships. This would ensure career readiness and advancement within the profession. The participants also called for the revisiting and modernising of policies like BBBEE to focus on equal opportunity and genuine empowerment rather than mere quota fulfilment. Political stability is highlighted as vital for economic improvement, with participants recommending better governance, transparency and accountability. Strengthening South Africa's infrastructure and the broader construction industry can reduce unemployment, while enhanced safety and security measures, such as crime reduction, can make South Africa more attractive for living and working.

The findings of this study have several important implications for policy and practice. To mitigate the emigration of quantity surveyors, it is crucial for policymakers to address the financial, social, political, and professional factors identified in this study. This could include implementing more competitive salary structures, improving workplace safety, addressing corruption and inefficiency in governance, and creating better career advancement opportunities. By tackling these issues, South Africa could reduce the brain drain and retain its skilled professionals, which is essential for the sustainability of the construction and built environment sectors. While this study provides valuable insights into the emigration of South African quantity surveyors, further research is needed to explore the long-term impact of these emigration trends on the country's construction industry. Future studies should also examine the effectiveness of the proposed strategies in retaining professionals and consider how similar factors influence emigration in other professional fields.

In conclusion, the emigration of South African quantity surveyors is driven by a complex interplay of financial, social, political, and professional factors. Addressing these issues requires targeted strategies that go beyond mere economic incentives. By understanding and acting on the factors identified in this study, policymakers and industry leaders can take meaningful steps to retain talent and strengthen the country's professional workforce. This research contributes to the broader discourse on brain drain and professional migration, offering actionable insights that can inform both policy and practice.

Recommendations

Building on the conclusions drawn from this study, several key recommendations are proposed to address the factors driving the emigration of South African quantity surveyors. These recommendations are rooted in the study's findings and aim to provide practical and actionable steps for stakeholders.

Firstly, it is crucial to establish comprehensive research and feedback mechanisms that continuously monitor the evolving concerns of professionals in the field. By implementing regular surveys and focus groups, industry leaders and policymakers can stay attuned to the challenges faced by quantity surveyors and adapt strategies accordingly. This ongoing dialogue will ensure that the solutions remain relevant and effective over time, addressing the financial and social pressures identified in the study.

In terms of professional development, promoting and expanding educational programs is essential. There is a need to increase funding and support for graduate programs, internships, and learnerships that offer real-world experience, mentorship, and clear pathways for career advancement. By creating more opportunities for professional growth, South Africa can retain its talent and reduce the appeal of emigration. This aligns with the study's conclusion that limited career opportunities are a significant driver of emigration.

Moreover, the study highlights the importance of regularly reviewing and updating policies like the Broad-Based Black Economic Empowerment (BBBEE). To ensure these policies are genuinely effective in promoting equal opportunities, it is recommended that a multi-stakeholder task force be established to review such policies every few years. This will help maintain their relevance and ensure they are achieving their intended outcomes, rather than merely serving as compliance checkboxes.

Stabilizing the political environment is another critical area of focus. The study found that political instability and corruption are significant push factors for emigration. Therefore, targeted reforms aimed at enhancing transparency, accountability, and good governance are recommended. This could involve

anti-corruption campaigns and governance improvement programs, which would help restore trust in the political system and make South Africa a more attractive place to live and work.

Improving safety and security in urban areas is critical for addressing high crime rates, which significantly contribute to emigration concerns in South Africa. Effective strategies include enhanced policing, community engagement, and infrastructure improvements. Research indicates that urban public spaces can foster safety and security, thereby reducing crime rates and promoting social cohesion (Kielek, 2022). Furthermore, the integration of community trust and safety perceptions is essential for improving children's well-being in urban contexts, highlighting the need for policies that enhance community engagement (Eriksson, Hochwälder & Sellström, 2011). Urban governance should prioritize safety as a fundamental aspect of urban planning, ensuring that safety measures are inclusive and address the needs of vulnerable populations (Gressgård, 2016; Tsoriyo, Ingwani, Chakwizira & Bikam, 2021). By implementing these initiatives, South Africa can alleviate one of the key social push factors contributing to emigration, ultimately fostering a more secure and stable environment for its residents (Ranaweera, 2024). By enhancing safety, South Africa can alleviate one of the key social push factors contributing to emigration.

Financial incentives are another important tool to retain professionals. The study suggests providing competitive salaries. Additionally, providing subsidies or grants for early-career professionals could help reduce the financial pressures that drive emigration. These measures would make staying in South Africa more financially viable for quantity surveyors, addressing one of the primary reasons for leaving.

Investment in infrastructure development is another key recommendation. The study highlights the need for improved infrastructure, particularly in the construction sector, to create more job opportunities and enhance the overall quality of life. A national infrastructure development plan, supported by both public and private investments, could stimulate economic growth and provide more stable employment for professionals.

Finally, engaging with the diaspora of South African quantity surveyors who have emigrated is crucial. By understanding their reasons for leaving and exploring what might entice them to return, stakeholders can gain valuable insights that could inform future retention strategies. This engagement could also open the door for repatriation, bringing skilled professionals back to contribute to the country's development.

In summary, a multi-faceted approach is essential to address South African quantity surveyors' financial, social, professional, and political concerns. By implementing these recommendations, stakeholders can create a more conducive environment for professionals to thrive, ultimately reducing the trend of emigration and ensuring the sustainability of the country's construction and built environment sectors.

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Impediments to Productivity in Sustainable Construction Projects in Eastern Cape, South Africa: a Literature-based Assessment of Construction 5.0's Potential to Mitigate the Challenges

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Abstract

The South African construction industry, a key economic driver, faces persistent productivity challenges, particularly in sustainable construction projects (SCPs). This study examines the technical and managerial impediments to productivity in SCPs and assesses the current literature regarding the potential of Construction 5.0 (C5.0) to address these challenges. A quantitative approach was used to collect data from 148 purposively sampled Grade 5-9 Construction Industry Development Board (CIDB) contractors in the Eastern Cape. Data was gathered via a structured questionnaire (Google Form) and analyzed with SPSS version 29.0 to identify major impediments to productivity in SCPs. Descriptive statistics, including mean and standard deviation, were used for data interpretation. High mean scores for design errors, changes during construction, delays in responding to requests for information, frequent change orders, and delayed payments of claims revealed an interplay of technical and managerial impediments. Based on the existing studies, the study advocates C5.0's potential to address these issues by enhancing collaboration, data management, and decision-making. The study's scope is limited to the Eastern Cape and relies on secondary data regarding C5.0 to mitigate these challenges. Further research is needed to enhance the robustness of the analysis and the generalizability of the findings to other regions. The study emphasizes the need for C5.0 adoption to improve productivity in SCPs. Industry practitioners should prioritize technology investment, training, and infrastructure. Policymakers can encourage C5.0 adoption through supportive regulations and incentives. This research contributes to the discourse on SCP productivity and the transformative potential of C5.0. It provides insights for industry practitioners, policymakers, and researchers seeking to improve project performance and sustainability, advocating for innovative technologies to transform traditional construction practices.

Keywords: Construction Business, Construction 5.0, Productivity, Skilled Workers, Sustainable Construction Projects.

Introduction

Economic growth hinges on construction industry productivity. However, this sector faces declining productivity despite increasing competition and efforts towards sustainable construction practices aligned with sustainable development goals (Agrawal and Halder, 2020). Low productivity plagues most construction projects, whether simple or complex. The South African construction industry plays a crucial role in service delivery and development, contributing roughly 3% to the Gross Domestic Product (GDP). Despite the importance of productivity to economic growth, South Africa's construction productivity ranks among the lowest in developing countries (Bierman, Marnewick, and Pretorius, 2016). This has been associated with a skilled worker shortage, a major business obstacle for 40% of South African construction organizations (Statistics South Africa report, 2018, Construction Industry Development Board (CIDB), 2019; Tshele and Agumba, 2014). The United Nations advocates sustainable development goals, which different industries, including construction, should promote. Sustainable construction projects (SCPs) aim to reduce environmental impact and use resources efficiently, but they often struggle with productivity issues due to complex technical and managerial

factors. Construction 5.0 (C5.0) could provide advanced technological solutions to improve productivity performance in SCPs. The integration of cutting-edge technologies could have the potential to significantly improve productivity in SCPs, ensuring that both efficiency and sustainability goals are met.

The Eastern Cape construction industry significantly contributes to provincial employment. However, skilled worker shortages are particularly severe in this region compared to the rest of South Africa (CIDB, 2019). Brain drain, with 12% of Eastern Cape natives migrating to other provinces, exacerbates this issue (Statistics South Africa report, 2018). In recent years, calls for sustainable construction practices have intensified to combat climate change (Windapo, 2016). However, due to the specialized skills required, productivity in sustainable construction projects (SCPs) often falls below traditional construction levels (Adebowale and Agumba, 2023). SCPs depend heavily on a workforce capable of efficiently handling both traditional and sustainable construction methods. The loss of skilled workers to other regions and the new skillset demanded by sustainable projects hinders many Eastern Cape contractors (Statistics South Africa report, 2018). A versatile workforce is critical for any region to thrive in today's era of rapid industrial revolution (Tshele and Agumba, 2014).

Although some productivity research has been conducted in the construction industry, there is a shortage of research that specifically focuses on productivity in SCPs. Consequently, it is essential to investigate the major impediments to productivity in SCPs. The primary objectives of this study are to determine the technical and managerial impediments to productivity in SCPs. Construction 5.0 emphasizes collaboration between humans and robots within complex construction environments, characterized by increased efficiency, safety, and quality (Naoom, 2016). Therefore, through existing literature, this study further assesses the potential of Construction 5.0 to mitigate the identified technical and managerial impediments to productivity in SCPs.

Literature Review

Sustainable construction projects and Construction 5.0

As the construction industry grapples with declining productivity, SCPs are gaining traction due to their focus on resource responsibility and environmental sensitivity (Marinelli, 2023). These projects aim to minimize the industry's environmental impact by incorporating practices like energy efficiency, green building materials, and water conservation strategies (Adebowale et al., 2023; Marinelli, 2023; Lima, Trindade, Alencar, Alencar, and Silva, 2021). Energy efficiency is a fundamental component of SCPs, as highlighted by Adebowale et al. (2023), who emphasize utilizing efficient technology and renewable energy sources. Lowering the environmental impact of transportation and promoting long-lasting, recyclable materials heavily depends on the use of green building materials that are locally sourced and environmentally benign (Lima, et al., 2021). Strategies for waste reduction and recycling are essential parts of sustainable construction, aiming to decrease the industry's historically large contribution to overall waste generation (Bogue, 2018). Construction projects can contribute to a circular economy by minimizing waste and recycling materials, thus reducing environmental impact and the need for new raw materials. Water conservation is another major priority, achieved through sustainable construction practices that integrate water-efficient technologies and systems to reduce usage and improve the overall management of water resources (Marinelli, 2023). SCPs are also increasingly incorporating green spaces and biodiversity considerations. Elements such as open spaces and green roofs enhance air quality and support nearby ecosystems, while also providing aesthetic appeal (Maskuriy, Selamat, Ali, Maresova, and Krejcar, 2019). Beyond environmental concerns, sustainable construction also has positive effects on the economy and public perception. The long-term financial benefits outweigh any initial expenditures; energy-efficient designs result in lower operating costs, and the use of durable materials reduces maintenance costs (Adebowale et al., 2023). Organizations involved in sustainable building projects often enjoy a positive public image, as customers, investors, and the community at large value enterprises that prioritize environmental responsibility (Lima et al., 2021).

However, addressing the issue of contractors' proficiency in utilizing modern technologies to deliver SCPs is crucial to fully benefit from these projects. The use of green building materials that are locally sourced and environmentally benign might require additional training for workers accustomed to traditional materials. This highlights the need for a skilled workforce adaptable to the evolving demands of SCPs. While SCPs aim to address environmental challenges, the adoption of C5.0 technologies has the potential to further enhance the productivity and efficiency of these projects. C5.0 builds upon the principles of sustainable construction by integrating cutting-edge technologies that enhance project

efficiency while maintaining environmental goals. For instance, automation, artificial intelligence, and data analytics can streamline construction processes, reduce waste, and optimize the use of green materials, thereby addressing key productivity impediments in SCPs. Although the transition from Industry 4.0 (I4.0) to Industry 5.0 (I5.0) is still ongoing, the corresponding vision of I5.0 has already emerged. I5.0 aims to bring the human factor back into the production system, with the collaborative work paradigm of human-robot collaboration at its core (Marinelli, 2023). C5.0 is an industry-specific derivative from I5.0, advancing interactions between robots and humans, which could potentially address the impediments to productivity in SCPs. Given that the actual use of interactive robots in construction is currently only experimental, it would be rational for the academic community to extend/adapt the C5.0 concept to include other technologies and applications with equivalent impacts on workers' well-being and the sustainability targets of the sector (Marinelli, 2023).

Impediments to productivity in construction projects

Table 1 presents major impediments to construction productivity. In South Africa, disruptions such as labour disputes impact safety, productivity, and profitability in the construction sector (Akogbe et al., 2015). The primary impediments to productivity in construction projects are broadly categorized into technical impediments and management impediments (Marinelli, 2023). Technical impediments include issues related to design and operational inefficiencies. Design errors and changes during construction significantly impact productivity by causing delays and rework (Hwang, Zhu, and Ming, 2017). In contrast, delays in responding to requests for information disrupt workflows, and unclear technical specifications lead to confusion and rework (Jarkas, Al Balushi, and Raveendranath, 2015). Poor construction methodology, including inadequate construction techniques and unsuitable site logistics such as storage locations, hampers efficiency (Maskuriy, 2020; Lima et al., 2021). While Maskuriy (2020) focuses on construction techniques, Lima et al. (2021) highlight logistics, suggesting that both aspects are critical but differ in their impact on productivity. Frequent change orders and delays in payment claims disrupt project flow and lead to rework (Hwang, Zhu, and Ming, 2017; Adebawale and Agumba, 2023). Adebawale and Agumba (2023) complement Hwang et al. (2017) by adding the dimension of financial delays to the technical challenges. Inspection delays and inadequate crew size could affect productivity by impeding progress and creating skill gaps (Adebawale et al., 2023; Tshele and Agumba, 2014). Tshele and Agumba (2014) emphasize the role of crew size, while Adebawale et al. (2023) consider inspection delays, suggesting a broader view of operational inefficiencies. Poor communication between project team members and a lack of periodic meetings contribute to misunderstandings and inefficiencies (Akogbe, Feng, and Zhou, 2015; Bogue, 2018). The comparison of Akogbe et al. (2015) with Bogue (2018) reveals that communication issues are pervasive across various impediments. These factors reflect significant technical impediments regarding how design and operational issues disrupt efficiency.

Management impediments such as a higher ratio of subcontracted work and poor material and equipment management introduce additional complexities affecting productivity (Hwang, Zhu, and Ming, 2017; Agrawal and Halder, 2020). Excessive overtime can lead to fatigue and safety issues, impacting long-term productivity (Sheikh et al., 2017). Sheikh et al. (2017) highlight the impact of fatigue, which contrasts with the broader managerial issues discussed by Hwang et al. (2017) and Agrawal and Halder (2020). Frequent client interventions and poor supervision disrupt workflows and affect performance (Adebawale et al., 2023; Tshele and Agumba, 2014). Adebawale et al. (2023) and Tshele and Agumba (2014) both identify disruptions caused by external factors, although they focus on different aspects such as client interventions and supervision. These management impediments underscore how administrative and organizational issues can significantly hinder productivity. The potential of C5.0 technologies to address these impediments should be considered. C5.0 technologies could enhance design efficiency, improve communication, and optimize information flow, addressing key technical and managerial challenges (Akogbe, Feng, and Zhou, 2015). Despite this, specific data on the efficacy of C5.0 technologies in mitigating these issues remains limited. Although specific data from this study on C5.0 technologies is limited, existing literature suggests their role in mitigating productivity issues in SCPs (Jarkas and Haupt, 2015). Jarkas and Haupt (2015) provide a foundation, yet their findings are not universally applicable, indicating a need for further investigation. The application of C5.0 solutions may offer strategic advantages in overcoming identified impediments and improving overall project performance. The construction sector's contribution to sustainable development underscores the need to address these productivity impediments (Ofori, 2007). Ofori (2007) emphasizes the broader impact of construction on sustainability, aligning with the need to address impediments identified in this study. While many impediments in traditional construction have been documented, limited research exists on

SCPs. This study aims to bridge this gap by identifying technical and managerial impediments in SCPs and exploring the role of C5.0 solutions in improving productivity (Iqbal et al., 2017; Akogbe, Feng, and Zhou, 2015). Iqbal et al. (2017) and Akogbe, Feng, and Zhou (2015) collectively suggest that SCPs may face unique challenges, reinforcing the need for targeted solutions.

Table 1: Impediments to construction productivity

Category	Impediments	Sources
Technical Impediments	Design errors and changes causing delays and rework	Hwang, Zhu, and Ming (2017)
	Delays in responding to requests for information, unclear technical specifications	Jarkas, Al Balushi, and Raveendranath (2015)
	Poor construction methodology	Maskuriy (2020)
	Poor site logistics	Lima et al. (2021)
	Frequent change orders disrupting project flow	Hwang, Zhu, and Ming (2017); Adebawale and Agumba (2023)
	Delays in payment claims leading to rework	Adebawale and Agumba (2023)
	Inspection delays and inadequate crew size creating skill gaps	Adebawale et al. (2023); Tshele and Agumba (2014)
	Poor communication between project team members	Akogbe, Feng, and Zhou (2015); Bogue (2018)
Management Impediments	Higher ratio of subcontracted work	Hwang, Zhu, and Ming (2017); Agrawal and Halder (2020)
	Poor material and equipment management	Hwang, Zhu, and Ming (2017); Agrawal and Halder (2020)
	Excessive overtime leading to fatigue and safety issues	Sheikh et al. (2017)
	Frequent client interventions disrupting workflows	Adebawale et al. (2023); Tshele and Agumba (2014)
	Poor supervision affecting performance	Adebawale et al. (2023); Tshele and Agumba (2014)

Research Methodology and Method

Research philosophy

This study adopts a positivist research philosophy that emphasizes objectivity and the use of quantifiable data to analyze the impediments to productivity in SCPs in the Eastern Cape Province. Positivism is appropriate for this study because it seeks to establish generalizable findings through measurable and observable data (Creswell and Creswell, 2017). This philosophy aligns with the research objective of identifying specific productivity challenges in SCPs and evaluating them through quantifiable measures.

Research method

The study was designed to analyze the impediments to productivity in SCPs, focusing on contractors registered in CIDB Grades 5 to 9. By employing a quantitative approach, this research provides an assessment of impediments to productivity in SCPs and advances potential solutions in line with C5.0. The quantitative approach was selected because it enables the collection of numerical data that can be statistically analyzed to derive meaningful insights. Quantitative methods are suitable for large sample sizes, providing objectivity and reliability in understanding trends and patterns related to SCP productivity (Bryman, 2016). In this case, a quantitative method allows for the investigation of impediments to productivity in SCPs, focusing on the perceptions of contractors in the Construction Industry Development Board Grades 5 to 9, which handle large-scale projects. However, a limitation of this approach is that it may not capture the depth of qualitative insights that could provide a richer understanding of the contextual factors affecting productivity.

The focus on Grade 5 to 9 contractors in the Eastern Cape Province was because these contractors typically engage in large-scale construction projects that are more likely to incorporate sustainable practices and advanced technologies. Consultants, while key stakeholders in construction, were not included because this study specifically targets the operational aspects of productivity at the contractor level, where on-site execution and management directly affect project outcomes (Marzouk and El-Rasas, 2014). Moreover, contractors are often the primary decision-makers in resource allocation and technological integration in SCPs, making them central to the study's objectives. Literature supports the use of contractor-based analysis in understanding construction productivity challenges, as contractors

face direct impacts from resource shortages, technical complexities, and workforce management (Jarkas and Haupt, 2015).

Sampling technique

A purposive sampling method was employed to select participants with specialized knowledge and experience in sustainable construction projects. The use of purposive sampling was chosen for its ability to target specific populations capable of providing relevant information for addressing the research questions (Palinkas et al., 2015). This method ensured that the participants could offer detailed insights into the productivity challenges within the industry. According to the CIDB online register, there were 638 contractors graded 5-9 registered in the Eastern Cape. Using the Krejcie, and Morgan (1970) formula, an appropriate sample size of 241 contractors was determined. Out of these, 148 contractors were purposively selected based on their experience in SCPs, as indicated by prior investigations into their organizations. While purposive sampling ensures the inclusion of relevant participants, it also introduces the potential for selection bias, as the sample is not randomly selected, which could limit the generalizability of the study's findings.

Data collection

Data were collected from key personnel within the selected contractors, including directors, construction supervisors, managers, site agents, engineers, quantity surveyors, and technicians. A total of 148 questionnaire surveys were distributed, of which 50 were fully completed and retrieved, resulting in a response rate of 33.78%. The questionnaire used a 5-point Likert scale to capture participants' perceptions of the impediments to productivity, ranging from 1 ("strongly disagree") to 5 ("strongly agree").

Data analysis and interpretation

Descriptive statistics in the form of mean scores (MSs) were used to analyze the research data as it suffices to achieve the study aim of ranking the SCPs' productivity impediments. MS range value was determined to ensure consistent classification and interpretations. For the 5-point scale, 1 was subtracted from 5, resulting in 4, which was then divided by 5, resulting in 0.8, forming the MS range (Muthambi, et al., 2022; Adebowale, 2018; Renault, et al., 2018). Consequently, the MS range for "strongly disagree" became $>1.00 \leq 1.80$, "disagree" became $>1.80 \leq 2.60$, "neutral" became $>2.60 \leq 3.40$, "agree" became $>3.40 \leq 4.20$, and "strongly agree" became $>4.20 \leq 5.00$ (Adebowale, 2018). The study reports on variables that respondents have a strong agreement with. In addition to mean score analysis, which provided insights into the central tendencies of responses, the standard deviation of the dataset was calculated to assess the degree of variability in responses, offering insight into the consistency of participant perceptions. The Statistical Package for the Social Sciences (SPSS) version 29 was used to facilitate data analysis. SPSS allowed for the calculation of measures of central tendency and dispersion. Cronbach's alpha was also computed to test the reliability of the scaled questions, yielding a coefficient of 0.76, which indicates acceptable internal consistency (Amirrudin, et al., 2021).

Research Results and Discussion

Contractor distribution by CIDB grading

Table 2 presents the CIDB grading for the selected contractors. The table shows that 24% of the contractors were in the grade 5 category, 14% were categorized as grade 6, and 8% were classified as grade 7. Contractors in grades 8 and 9 comprised 24% and 30%, respectively. The table indicates that the majority of the contractors who participated in this study were in CIDB grades 8 and 9.

Table 2: CIDB grade of the contractor

CIDB Grade	No	Percentage (%)	Cumulative (%)
5	12	24	24
6	7	14	38
7	4	8	46
8	12	24	70
9	15	30	100
Total	50	100	

Distribution of respondents by professional role

It is evident from Table 3 that 26% of the respondents were construction managers, followed by a notable 24% who were construction supervisors. Site agents accounted for 18% of the respondents, while site engineers represented 14%. The table indicates that 10% of the respondents were site technicians, and a mere 6% were directors. The majority of the respondents were construction managers and site agents, constituting a significant 50%.

Table 3: Role of the respondents

Role	No	Percentage (%)	Cumulative (%)
Directors	3	6	6
Construction Supervisor	12	24	30
Construction Manager	13	26	56
Site Agents	9	18	74
Site Engineer	7	14	88
Site Technician	5	10	98
Quantity Surveyor	1	2	100
Total	50	100	

Technical impediments to productivity in SCPs

The survey findings (Table 4) underscore critical technical impediments to productivity in SCPs in the Eastern Cape.

Table 4: Technical factors

Factors	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std.	Rank
Design errors and changes during construction	50	0.0	0.0	0.0	64.0	36.0	4.36	.485	1
Delays in responding to "requests for information" (RFI)	50	0.0	0.0	2.0	68.0	30.0	4.28	.497	2
Unclear technical specifications	50	0.0	0.0	18.0	60.0	22.0	4.04	.638	3
Reworks	50	0.0	0.0	14.0	74.0	12.0	3.98	.515	4
Poor construction methodology	50	0.0	0.0	34.0	62.0	4.0	3.70	.544	5
Poor site logistics and management	50	0.0	8.0	40.0	48.0	4.0	3.48	.707	6
Average	50						3.97		

These include design errors and changes and delays in responding to information requests, with Likert scale ratings >4.20 and ≤ 5.00 , indicating that respondents strongly agree on these factors. This result is consistent with findings in studies on traditional construction projects, including Hwang, Zhu, and Ming (2017), Jarkas, Al Balushi, and Raveendranath (2015), Odesola and Idoro (2014), and Jarkas, Radosavljevic, and Wuyi (2014). Design errors and changes during construction emerged as significant impediments, leading to delays and increased costs. These issues often necessitate rework and disrupt project timelines, reflecting the conclusions of previous research highlighting design-related issues as major barriers to productivity (Hwang, Zhu, and Ming, 2017; Jarkas, Al Balushi, and Raveendranath, 2015). For instance, Jarkas and Haupt (2015) discuss how design changes can introduce substantial inefficiencies and additional costs. This study's findings corroborate these observations by emphasizing the persistent challenges posed by design errors and changes. Delays in responding to requests for information (mean = 4.28, SD = 0.497) is also a significant impediment. Such delays can impede workflow and extend project duration, aligning with previous research findings (Hwang, Zhu, and Ming,

2017; Jarkas, Al Balushi, and Raveendranath, 2015). Effective communication is crucial for maintaining project momentum, and these delays underscore the need for improved information management systems. This study's results reflect broader issues identified in the literature, suggesting that addressing communication delays could be vital for enhancing productivity in SCPs. Unclear technical specifications and the need for rework (mean = 4.04 and 3.98, respectively) are also significant impediments. These findings are consistent with literature indicating that ambiguity in specifications and rework contribute to inefficiencies (Jarkas, Al Balushi, and Raveendranath, 2015). The prevalence of poor construction methodology and site logistics (mean = 3.70 and 3.48, respectively) further highlights operational inefficiencies impacting productivity. Jarkas and Haupt (2015) emphasize the role of methodological issues in disrupting project efficiency.

Although the survey did not specifically collect data on C5.0 technologies, existing literature suggests these technologies could address some of the identified technical impediments. C5.0 integrates technologies like AI, digital twins, and advanced robotics, which can reduce design errors by improving precision through automated design processes and simulations (Adebowale and Agumba, 2023; Marinelli, 2023). The use of Building Information Modeling allows for real-time updates and communication between stakeholders, minimizing changes during construction and ensuring that design modifications are identified and resolved before construction begins (Maskuriy et al., 2019). Additionally, delays in responding to information requests can be mitigated by adopting cloud-based platforms that allow for seamless communication and immediate access to project data, ensuring faster decision-making and issue resolution (Marinelli, 2023). Adebowale (2018) highlights the potential of a multi-stakeholder approach, supported by digital tools, to improve productivity in the South African construction industry. Agrawal and Halder (2020) identify the potential of digital technologies to enhance labour efficiency, while Bogue (2018) reports the role of robotics and automation in addressing technical challenges. These studies collectively emphasize the transformative potential of C5.0 technologies in overcoming technical impediments and enhancing overall productivity in SCPs. The results of this study reflect consistent issues with design errors, information delays, and unclear specifications, as identified in traditional construction contexts. However, the integration of C5.0 technologies presents a significant opportunity to address these challenges. Comparing these findings with previous research, it is evident that while traditional methods have identified and documented these barriers, C5.0 technologies offer innovative solutions that could mitigate some of these issues. This broader context underscores the need for construction professionals, including quantity surveyors, to embrace and adapt to evolving technologies to enhance productivity and address the specific challenges faced in SCPs.

Management impediments to productivity in SCPs

Table 5 presents management impediments to productivity in SCPs. The survey findings reveal that frequent change orders and delays in payments are the most significant management impediments to productivity in SCPs in the Eastern Cape. Frequent change orders, with a mean score (MS) of >4.20 and ≤ 5.00 , rank as the most significant impediment. This high rating underscores the broad consensus on the disruptive nature of change orders, which can lead to delays, increased costs, and diminished project efficiency. Pomtepkasemsant and Charoenpompattana (2015) indicate that frequent changes in project scope are a substantial barrier to productivity. Some studies also corroborate this, showing that change orders disrupt project workflows and increase costs (Adebowale, 2018). To mitigate these challenges, advanced project management tools such as project management software can provide real-time updates and comprehensive tracking of project modifications (Marinelli, 2023). These tools enable more accurate forecasting and adaptation to changes, thus reducing the negative impact of frequent change orders on productivity. The necessity of such tools is further supported by research highlighting their effectiveness in managing change orders and maintaining project efficiency (Marinelli, 2023). Similarly, delays in payments of claims, with an MS of >4.20 and ≤ 5.00 , are identified as another critical impediment. Payment delays can create financial strain on contractors and subcontractors, leading to disruptions in project schedules and overall productivity. Bierman, Marnewick, and Pretorius (2016) emphasize the financial challenges associated with delayed payments. Implementing financial technologies such as blockchain for transparent and efficient payment processing can address these issues. Blockchain technology can streamline payment workflows, enhance financial transparency, and reduce the risk of delayed payments (Adebowale and Agumba, 2023). This technology offers a promising solution to the financial challenges faced in SCPs, as suggested by research on its application in construction (Marinelli, 2023). The survey also identified other management factors, such as inspection delays, inadequate crew size and composition, poor labour supervision, and poor

communication between project teams. These factors, with MS ranging from 3.02 to 3.92, reflect ongoing challenges in project management. Inspection delays, for instance, can impact project timelines and efficiency (Jarkas and Haupt, 2015). Inadequate crew size and poor labour supervision can further exacerbate productivity issues, reflecting the importance of effective workforce management (Adebowale, 2018).

While traditional project management practices have highlighted these challenges, integrating C5.0 technologies offers innovative solutions. C5.0 technologies, including advanced project management software, digital communication tools, and blockchain for financial transactions, present opportunities to overcome these management impediments. For instance, digital tools can enhance communication and collaboration among project teams, reducing delays and improving coordination (Adebowale and Agumba, 2023). Blockchain technology's potential to streamline payment processes can address financial strains, as noted in Marinelli (2023). These technological advancements align with the broader trend towards integrating digital solutions in construction to improve productivity and efficiency. The high significance of frequent change orders and payment delays underscores the need for construction professionals to adopt innovative management strategies. Traditional practices may no longer suffice in addressing the complexities of modern SCPs. The integration of digital tools and technologies, as suggested by Adebowale and Agumba (2023), is essential for overcoming these challenges. The findings highlight the urgent need for the construction industry to adapt to evolving technologies to enhance productivity and address management impediments effectively.

Table 5: Management factors

Factors	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Std.	Rank
Frequent change orders in the project	50	0.0	6.0	2.0	36.0	56.0	4.42	.810	1
Delay in payments of claims	50	0.0	0.0	20.0	38.0	42.0	4.22	.764	2
Inspection delays	50	0.0	2.0	20.0	62.0	16.0	3.92	.665	3
Inadequate crew size and composition	50	0.0	8.0	20.0	60.0	12.0	3.76	.771	4
Poor labour supervision	50	0.0	18.0	12.0	68.0	2.0	3.54	.813	5
Poor communication between project team	50	2.0	8.0	34.0	46.0	10.0	3.54	.862	5
Lack of periodical meetings	50	2.0	2.0	50.0	38.0	8.0	3.48	.762	6
Frequent client's intervention	50	0.0	16.0	22.0	62.0	0.0	3.46	.762	7
Poor material/equipment management	50	0.0	20.0	24.0	54.0	2.0	3.38	.830	8
Excessive overtime	50	10.0	10.0	44.0	36.0	0.0	3.06	.935	9
Higher ratio of subcontracted work	50	8.0	30.0	24.0	24.0	14.0	3.06	1.202	9
Unsuitability of storage location	50	2.0	18.0	56.0	24.0	0.0	3.02	.714	10
Average	50						3.57		

Conclusion

Despite extensive research aimed at addressing productivity challenges in the construction sector, attention to SCPs remains limited. This study investigated technical and managerial impediments to productivity in SCPs and assessed the potential of C5.0 technologies to enhance productivity from a literature position. Significant technical impediments include design errors, changes during construction, and delays in responding to information requests. From a management perspective, frequent change orders and delays in payments of claims are the critical barriers to productivity. These results suggest that SCPs face many of the same challenges as traditional construction projects. However, given SCPs' focus on sustainability, it is essential to explore whether unique project attributes may further influence these factors.

Given the identified technical and managerial impediments to productivity in SCPs, the study advocates the potential of C5.0 to mitigate these impediments through digital technologies. However, successful adoption of C5.0 will depend on a human-centric approach that considers industry-specific dynamics. This shift towards digitalization could alleviate longstanding productivity challenges if accompanied by adequate training, organizational change, and supportive regulatory frameworks.

Recommendations

To address the identified technical and managerial impediments to productivity in sustainable construction projects, it is recommended that:

- Construction professionals prioritize the strategic integration of Construction 5.0 technologies, such as Building Information Modeling (BIM) and digital platforms, to minimize design errors, improve communication, and optimize resource management.
- Organizations invest in training programs to build the digital literacy and adaptability of construction teams. This will ensure that employees can effectively use Construction 5.0 technologies and leverage their potential benefits.
- Management implements organizational changes to foster a culture of innovation, collaboration, and data-driven decision-making. This includes implementing policies that promote real-time communication, minimize change orders, and streamline payment processes.
- Policymakers provide incentives and regulations to encourage the adoption of Construction 5.0 technologies in the construction sector. This could include tax breaks, grants, and regulations that promote digitalization and sustainable practices.

Further research should be conducted to gather primary data on the adoption of C5.0 technologies in SCPs. This would ensure a more rigorous analysis to validate the findings of this study and to explore whether SCPs face unique impediments due to their sustainability focus. Future studies should also investigate the broader economic, environmental, and social impacts of C5.0 adoption, ensuring that sustainability goals are met alongside productivity improvements in the construction industry.

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Implementation of Artificial Intelligence to Enhance Communication Among Construction Project Stakeholders in Namibia

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Abstract

This study aims to investigate the implementation of Artificial Intelligence (AI) to enhance communication among construction project stakeholders in Namibia. Namibian construction projects experience delayed feedback from team players and stakeholder conflicts due to a lack of stakeholder engagement and collaboration, which is believed to be emanating from poor communication strategies. This study can enhance construction project stakeholder communication utilising AI technologies in Namibia. The study adopted a quantitative approach, and 92 questionnaires were administered to registered construction professionals and building contractors randomly sampled in Khomas and Erongo Regions in Namibia. Descriptive statistics and correlation analysis were used to analyse quantitative data and investigate AI adoption in construction project communication. The results revealed that AI implementation in construction project communication in Namibia is yet to be fully embraced. The study also found that the lack of transparency and delays in feedback between stakeholders were the major challenges experienced in adopting AI. Data was only collected in Namibia's Khomas and Erongo regions, limiting the findings' generalizability. Future research should focus on the perceptions of all construction stakeholders in all Namibian regions to obtain a holistic view of the extent of AI adoption in construction project communication in other contexts. The results cannot be generalised to all contexts because of the differences amongst jurisdictions. The study is instrumental in enacting systems for using AI to improve construction project communications by project managers and clients. AI implementation in construction project communication has received less attention in research. This study will be pivotal in streamlining the construction communication process necessary for project success.

Keywords: Artificial Intelligence, Project Communication, Construction Stakeholders, Namibia.

Introduction

While AI application in the construction sector seems to be flourishing in Global North countries, little has been witnessed in the Global South countries (Hoffmann and Nurski, 2021; Nel, 2024)). A study done in Nigeria has revealed that the adoption of AI is still in its infancy as shown by the low use of BIM in the construction industry (Okereke, Muhammed and Eze, 2021). Abioye et al., (2021) have also noted that the adoption of AI in developing economies is still a challenge as stakeholders are still sceptical of the return on investment of such innovations. In South Africa, Makaula, Munsamy and Telukdarie (2021) posit that AI in construction is yet to be fully appreciated except for other technologies like BIM and its use by contractors on communication of machine hours and maintenance schedules for hired plant. Therefore, there is a low adoption rate of AI in business operations in the African context. Similarly, basic automation by project stakeholders is a stepping stone in fully appreciating the value of AI in enhancing the communication process (Wamba-Taguimdje et al., 2020). Further, AI results in the avoidance of major causes of conflicts and problems in the construction sector.

Considerable research has been undertaken on AI use though few studies were focusing on its use in construction project communication. For example, research has shown that few African countries such as Algeria, Egypt, Ghana, Kenya, Nigeria, and South Africa have established mechanisms and

institutions responsible for integrating AI in operations in all sectors of the economy (Arakpogun et al., 2021). Oxford Insights, (2024) have shown that most African countries have the lowest AI readiness index on a worldwide basis. Tunji-Olayeni, Aigbavboa and Oke, (2022) researched on critical success factors for AI integration in Nigerian construction where Institutional, behavioural, cost, knowledge, infrastructure, technical and trust were amongst the highly rated factors. Gómez-ferrer (2017) researched the importance of AI in addressing communication problems between actors in construction projects in the United Kingdom and concluded that AI is being implemented in many construction companies to improve productivity and minimise waste. These previously mentioned research did not provide enlightenment on prospects brought by AI in addressing communication challenges experienced on construction projects. Adoption of AI is still in its infancy though its importance in improving information dissemination among project stakeholders was evident.

AI integration in business operations is associated with beneficial improvements targeted at efficiency and waste reduction. Regona et al. (2022) found out that AI eases the logistical burden, enhances documentation, as well as reduces disputes with various stakeholders. Obiuto, (2024), however, posits that the rise of AI in the construction industry might revamp the communication processes by the integration of advanced technologies to bridge site and office communications. However, Raliile and Haupt (2023), claim that AI result in a series of errors, delayed actions, and misrepresentation of facts. Nel (2023) claims that meetings propagate bored and disinterested officials who don't understand proceedings but are afraid to ask questions, resulting in personal conflicts. Hence, AI adoption on construction projects has insurmountable potential to address the negative effects associated with meetings.

It must also be noted that in both developed and developing countries, the implementation of AI has also been met with a fair share of challenges (Ahmed, 2020). Lack of lucid legal frameworks governing data protection, and regular heavy investments in technological training and development of staff are some of the challenges that have been noted (Council of Europe, 2019; Davis and Trott, 2024). Consequently, some consultants are not keen on implementing AI tools to foster industry collaboration due to the fear of losing control of their intellectual property. In this regard, Li, Wang, and Wu (2021) allude that it might be difficult for all the stakeholders to implement AI as it flourishes if all stakeholders are connected.

In Namibia, the use of AI is still low and haphazard. Africa Talks Construction, (2023) reported that Namibia Construction Company has successfully implemented an AI application called Open Space while constructing the Mokuti Etosha Lodge. This AI technology enables the contractor to manage remote sites by assessing the site, taking real-time photos, checking safety on-site, and issuing instructions. To date, in Namibia, site meetings are mostly done monthly, and they are the major communication hub where all stakeholders gather and discuss matters related to the projects (Africa Talks Construction, 2023). Namibian construction projects have been affected by communication problems which can be solved through AI. Shihepo, (2023) points to delays in construction as emanating from poor contract management and technical incapacity of Contractors which could potentially be solved through the adoption of AI in construction project communication. A case of Frankly Enterprises CC v Ohiozebau (2023) was brought to the High Court of Namibia where the applicant failed to complete extra work in time due to late communication of the intended revision of the construction drawings.

In this research, the problem being studied is that of the failure to implement AI in streamlining construction project communication characterised by delays, constant budget revisions, as well as disputes arising due to information deficiencies. This study aims to investigate the implementation of AI to enhance communication among construction project stakeholders in Namibia. The study will assist the construction industry players to understand the nexus between AI and the project communication process and harness its potential benefits targeting to improve project performance. Hence, the provided brief background of the subject matter forms the anchor upon which this study was undertaken in the Namibian context. The following section will outline the literature review on AI followed by the research methodology and the results. Discussions will be undertaken on the presented results followed by the conclusion and the recommendations.

Literature Review

Artificial Intelligence (AI) in communication

Communication is the important act of conveying information from one party to another through commonly understood symbols and semiotic procedures (Nyanga, 2016). Olaniran, (2015) asserts that communication could either be vertical from lower-level responsibilities to management in project team organisations or horizontal with customers and within project teams. Communication has diverse effects on construction projects ranging from inexperienced interpretation of working drawings, poor and distorted information and late dissemination of information. Construction project communication of team players is essential, as ineffective messaging and the poor communication potentially lead to negative outcomes (Malik et al., 2021). For instance, Senaratne and Ruwanpura, (2016) found out that effective construction project communication increases productivity and reduces waste. Olaniran, (2015) claims that inadequate information dissemination between project team players is the major cause of project failure. These findings hence have positive implications for construction project success.

The major purpose of construction project communication is the dissemination of information within the required period, thus delay in receipt of information is one form of waste that can be experienced. Artificial Intelligence (AI) is a rapidly developing field involving computer systems to perform tasks normally requiring human intelligence, including communication (Zohuri and Behgounia, 2023; Khaleel and Jebrel, 2024). AI use in construction communication enhances data analysis from project plans, blueprints, and sensor data, to predict outcomes and optimise processes (Obiuto et al., 2024). Automation in construction project communication can potentially reduce bottlenecks found in the process and consequently improve project success.

AI use in communication is gaining momentum and has ushered a new way of generating, communicating, and consuming data (Zerfass et al., 2020). Expansion of digital value chain to enable communication between products and their environment and business stakeholders is part of the broader Industry 4.0 initiatives (Gunkel, 2012). Machines and software have continuously been developed to imitate significant human cognitive and emotional abilities suitable for effective communication (Jakesch et al., 2019). Guzman and Lewis (2020), support this and claim that self-learning or intelligent systems will be used in mass and personal communication. Research recognises the implementation of virtual and augmented reality, big data and automation as part of the overall use of AI in strategic communication (Wiesenbergh, Zerfass, and Moreno, 2017; Guzman and Lewis, 2020). In a study undertaken by (Rimington, Dickens and Pasquire, 2015), respondents echoed that they make use of physical face-to-face communication whilst practically they were making use of technology in communication. AI integration into communication has inevitably witnessed in various platforms and is expected to increase.

AI infusion into construction communication management is accompanied by several benefits and problems. AI techniques are capable of supporting construction companies in reducing complexity and uncertainty (Guzman and Lewis, 2020). AI technologies such as Augmented Reality (AR) can be employed as an effective communication mechanism due to the vast amount of hidden data in construction sites. Additionally, cloud and BIM-based and social media platforms can efficiently improve collaboration and communication even across company borders (Oesterreich and Teuteberg, 2016). However, use of AI on construction projects has been associated with the loss of interpersonal skills of the project stakeholders (Rimington, Dickens and Pasquire, 2015). Further lack of physical face-to-face communication eliminates the “subliminal messages given by body language” (Rimington, Dickens and Pasquire, 2015, p. 1369), thereby limiting communication effectiveness. Without undermining the negative effects proffered by AI integration into construction project communication, the world has been presented with another change that it cannot do without as all sectors are fully embracing automation in business operations.

AI tools that can be used to enhance communication

Various AI tools can enhance communication among construction project stakeholders (Kumar et al, 2021). These tools vary, and their selection depends on the specific goals or challenges stakeholders aim to address in their communication processes. Some of the most prominent tools include Natural Language Processing (NLP), Virtual Assistants, the Internet of Things (IoT) as well as Image and Video Analysis tools.

NLP tools make use of machine learning algorithms to understand and process human language. In the construction industry, NLP can be applied to various communication channels such as emails, project documentation, and meeting transcripts (Bilal et al., 2016; Baker et al., 2020) to analyse information to gauge stakeholders' attitudes. NLP tools can improve communication efficiency and enable stakeholders to focus on critical information. Bilal et al. (2016) further claims that NLP is a system that understands and processes human language, allowing project managers to extract crucial information from various sources. Thus, NLP tools can analyse and interpret text data, enabling stakeholders to extract meaningful insights from project documents, reports, and communication channels.

Virtual assistants and chatbots are also AI-powered conversational agents that capable of providing administrative services to clients remotely and interact with stakeholders in natural language (Bilal et al., 2016). Additionally, Virtual Assistants and chatbots provide instant responses to common queries, project updates, and assist with information retrieval. This technology thus provides personalised and timely assistance. Virtual assistants powered by AI offer project managers an invaluable resource to streamline communication. These assistants can schedule meetings, send automated updates, and provide quick access to relevant project information, enabling project managers to save time and maintain effective communication (Kumar et al., 2021). Furthermore, Gamil and Rahman (2022) explained that virtual assistants and chatbots can provide real-time support and information to construction stakeholders.

Construction communication through AI can also be undertaken through image and video analysis tools capable of processing visual construction site data captured from drones, or surveillance cameras. These tools can automatically detect objects, track progress, identify safety hazards, and monitor compliance with design specifications (Dash and Sharma, 2022). By extracting meaningful insights from visual data, stakeholders can communicate effectively about site conditions, identify potential risks, and take prompt actions. For example, using computer vision techniques, AI tools can identify safety violations, equipment malfunctions, or deviations from the planned construction process, allowing stakeholders to address issues proactively (Gamil and Rahman, 2022).

The IoT involves connecting physical devices and sensors to collect and exchange data. In the construction industry, IoT devices and sensors can monitor various aspects such as temperature, humidity, vibration, and equipment performance (Darko et al., 2017). AI algorithms can analyse the real-time data generated by IoT devices, providing stakeholders with valuable insights (Kumar et al., 2021). For example, AI can detect anomalies, predict equipment failures, or identify energy inefficiencies. By integrating IoT data with communication platforms, stakeholders can stay informed about project conditions, collaborate on data-driven decisions, and address issues promptly (Dash and Sharma, 2022).

Effects of implementing AI tools to enhance communication

The adoption of AI comes with both positive and negative effects in the communication processes of construction projects. According to (Abbas, 2024; Silitonga and Jin, 2024), AI-powered systems can automatically classify, tag, and organise project documents based on their content. By utilising techniques such as NLP and machine learning, AI algorithms can analyse the content of documents, extract relevant information, and categorise them accordingly. This automation streamlines the process of organising project documentation, making it easier for stakeholders to locate and access the information they need. It eliminates manual effort and human errors associated with manual document management, ensuring that stakeholders have quick and accurate access to project documentation (Wiesenberg et al., 2017). The data and information from various sources or stakeholders can be efficiently searched and retrieved using AI (Wang, 2019). By analysing the content and metadata of documents, AI algorithms can also provide advanced search capabilities that go beyond simple keyword matching (Holzmann and Lechiara, 2022).

Data is abundant in construction projects, and AI can help stakeholders harness the power of this data for better decision-making (Hoffmann and Nurski, 2021). AI algorithms can process and analyse large volumes of data from various sources, including project management systems, sensors, and weather forecasts (Wiesenberg et al., 2017). By identifying patterns, trends, and correlations, AI systems provide stakeholders with valuable insights and actionable information (Wang, 2019). This data-driven decision-making empowers stakeholders to communicate effectively based on accurate and timely information,

leading to improved project outcomes. (Vinuesa et al., 2020) conclude that AI enhances data collection and integration. Thus, it has been proved that AI can automate the collection and integration of data from various sources within the construction ecosystem in an effective and efficient way (Holzmann and Lechiara, 2022).

According to Zeffass et al. (2020), AI algorithms can optimise project scheduling and coordination thereby improving communication among stakeholders. These algorithms consider project deadlines, resource availability, and dependencies to generate optimised schedules (Wiesenberg et al., 2017). Thus, this is important as AI-powered systems help stakeholders coordinate activities, ensuring that tasks are assigned and communicated efficiently. Therefore, AI enhances collaboration, minimises conflicts, and improves overall communication throughout the project lifecycle (Darko, 2017). Raisch and Krakowski (2020) also support that AI provides a good basis for optimised resource allocation thereby minimising conflicts and maximising efficiency.

Challenges in using AI tools in communication

The full embrace of AI in business operations is associated with various challenges. Firstly, construction projects experience problems in harmonising disparate data generated from various sources such as sensors, project management software, BIM models, and communication platforms (Regona, Yigitcanlar and Xia, 2022). This data is often siloed, stored in different formats, and spread across multiple systems. AI is also challenged by data quality issues and consistency (Agyekum et al., 2020). In addition, Hlávka (2020), point out that AI tools acquire aspects of confidential and proprietary data that might cause serious disruptions to privacy matters in separate construction parties. Therefore, AI use in construction presents data confidentiality risks capable of divulging information that may put organisations at the detriment of their competitors.

In construction projects, data may be compromised by incompleteness, inconsistencies, errors, or bias. For example, measurements taken on-site might have variations or inaccuracies. Poor data quality can significantly impact the performance of AI models, leading to incorrect predictions, sub-optimal recommendations, or biased outcomes (Aldoseri, Al-Khalifa and Hamouda, 2023). Thus, AI relies on accurate and comprehensive data to make informed decisions necessary for effective construction project communications. This can limit the accuracy of AI algorithms and make it difficult to provide actionable insights. If the data used to train the AI is incomplete, inaccurate, or biased, the system's output could also be unreliable (Ferrara, 2024). Construction professionals may exhibit skepticism or resistance due to concerns about job security, lack of familiarity with AI tools, or perceived complexities in their implementation (Gomez-Ferrer, 2017). Additionally, some labour unions and professionals still view the rise of technology in the workplace as a threat to human jobs (Zeffass, Hagelstein and Tench, 2020). Similarly, AI use is deterred by perceived job displacement, where construction professionals may have concerns about AI replacing human jobs or reducing their role in decision-making processes (Rawashdeh, 2023). However, Jarrahi (2018) argues that AI should be deployed to augment human capabilities rather than replace human workers as construction communication often requires collaboration between humans and AI systems.

The successful adoption of AI tools in construction projects relies on user acceptance and willingness to embrace new technologies. Acceptance and adoption of AI in communication is normally hindered by fear of job displacement (Guzman and Lewis, 2020). Purdy and Daugherty (2021) explain that the construction industry may have limited exposure to AI technologies, and there can be a lack of familiarity and understanding among users regarding how AI can benefit their specific workflows and processes. Construction industry players cannot be expected to accept these technologies if there is a low level of awareness of the AI tools. This, according to Ahmed (2020), can create resistance or skepticism towards adopting AI in communication.

Research Methodology and Method

The study employed quantitative approach where a closed-ended questionnaire was utilised to collect quantitative data. Questionnaire survey was also utilised in construction communication related studies by several authors (Doloi, 2009; Kania, Radziszewska-Zielina and Śladowski, 2020). The effect of AI in construction projects and its effectiveness on project communication were determined through a quantitative method. Several studies employed systematic literature reviews, structural modelling and case studies in research on use of AI in communication (Olaniran, 2015; Makaula, Munsamy and

Telukdarie, 2021; Malik et al., 2021) thus, a questionnaire survey will assist in bridging the gaps that are obtained from using qualitative based research methods.

The study focused on construction consultants, including contractors operating in the Khomas and Erongo Regions of Namibia. About 70% of the registered construction consultants reside in Windhoek and Erongo, thus these two regions give an acceptable basis to proffer representative insights on the phenomena being studied in Namibia. Study participants were registered members of the Association on Engineering Council of Namibia (AENC), Institute of Namibian Quantity Surveyors (INQS) and Namibia Institute of Architects (NIA) and the Construction Industries Federation of Namibia. Stratified random sampling was used to select survey respondents and a sample size of 92 was adopted. Descriptive statistics and correlation analysis were used to analyse quantitative data. Kibert (2016) and Abioye et al., (2021) posited that these methods of data analysis are appropriate for this type of study.

Research Results

This section presents the demographic data of respondents including the data on implementation of artificial intelligence to enhance communication on construction projects in Namibia. A total of 91 questionnaires were administered to different registered construction professionals and contractors. Out of 91 questionnaires distributed, 50 were obtained yielding a 55% response rate. Sauro and Lewis (2016) claim that a response rate between 21 and 28 respondents could yield accurate low-risk data. From the survey that was undertaken, the respondents were requested to indicate their professions. The results are shown on table 1.

Table 1: Profession of respondents

	Contractors	Architects	Engineers	Quantity surveyors	Total
Frequency	38%	12%	16%	34%	100%

38% were contractors, and 34 % was constituted by Quantity Surveyors. Sixteen percent was constituted by engineers and 12% was constituted by architects. The researcher also conducted 6 interviews with key informants in the construction industry. This comprised 2 contractors, 2 qualified architects owning consultancy firms in Namibia, 1 qualified quantity surveyor in the Ministry of Public Works in Namibia, and 1 qualified civil engineer.

Extent of implementing AI is being used as a tool to enhance communication

The respondents were asked to indicate if they were aware of AI and its application on construction projects. All the participants indicated that they are familiar with AI, which suggests that they could provide informed insights. The respondents were further asked if they have used AI in executing communication processes on construction projects. Survey results showed that 80% of the respondents do not use AI in their communication processes while 20% have used AI. Eight percent of the participants who have utilised AI on construction project communication made use of Generative AI (ChatGPT), while 20% were making use of BIM. This implies that the few respondents are currently using AI in Namibia.

The respondents were given a table to rate the extent to which selected AI tools were utilised in construction project communication on a five-point Likert scale, where 1=never; 2=rarely; 3=sometimes; 4=often; 5=always. The results are shown in Table 2. The mean interpretation was based on a 5-point Likert scale range as follows: MSs>1.00 ≤ 1.79 (never), MSs>1.80 ≤ 2.59 (rarely), MSs>2.60 ≤ 3.39 (sometimes), MSs>3.40 ≤ 4.19 (often) and MSs>4.20 ≤ 5.00 (always).

Table 2: Extent of implementing AI technologies

AI Tools/Technologies	MEAN	SD	RANK
Image and Video Analysis	4.0	1.13	1
Speech Recognition	3.8	0.78	3
Augmented Reality (AR) and Virtual Reality (VR):	3.72	1.17	2
Predictive Analytics	3.66	1.21	4
Natural Language Processing (NLP)	3.56	1.01	5
Virtual Assistants	3.5	1.23	6
Collaborative Project Management Platforms	2.46	1.03	7

Table 2 above shows that the AI technology that is used to a higher extent is image and video analysis which had a mean rating of 4. This shows that image and video analysis is often used in construction project communication. This implies that construction project stakeholders obtain construction site data in real time which helps address health and safety matters, remedies to workmanship and team interactions. Consequently, the preparation of construction valuations based on real-time progress is eased.

Five other AI technologies such as virtual assistants, NLP, speech recognition, AR and VR and predictive analytics had mean ratings ranging from 3.5 to 3.8 indicating that they are sometimes used. These results imply that construction project stakeholders sometimes adopt these technologies in construction project communication. The results also show that Collaborative Project Management Platforms had a mean rating of 2.46 meaning that this AI technology is rarely used in construction project communication. This entails a lag in AI implementation in communication as most communication is expected to be undertaken on collaborative working platforms.

Challenges experienced when using AI in construction project communication

The respondents were asked to rate the challenges experienced when using AI as a communication tool based on construction projects using a 5-point Likert scale was used where 1=Not frequently 2=less frequently 3=moderate 4=frequently 5=Very frequent. Table 3 below shows the responses obtained from the survey. The mean interpretation was based on a 5-point Likert scale range as follows: MSs>1.00 ≤ 1.79 (not frequently), MSs>1.80 ≤ 2.59 (less frequently), MSs>2.60 ≤ 3.39 (moderate), MSs>3.40 ≤ 4.19 (frequently) and MSs>4.20 ≤ 5.00 (very frequent).

Table 3: Challenges experienced when using AI in construction project communication

Communication Challenges	MEAN	SD	Rank
Lack of transparency due to its complexity	4.12	1.17	1
Delays in feedback between stakeholders due to variability in AI adoption	3.96	1.12	2
Ineffective reporting systems due to lack of quality data	3.84	1.26	3
Lack of full information (quality data)	3.7	1.03	4
Different levels of education	3.78	1.21	5
Fragmented communication channels	3.74	1.17	6
Lack of regular stakeholder engagement	3.72	1.20	7
Conflicts on valuations due to errors in AI communication algorithms	3.64	1.21	8
Workplace disputes due to misinterpretation	3.62	1.04	9
Misinterpretation of information such as drawings and instructions	3.6	1.28	10
Biased decision-making	3.52	1.14	11
Unclear document management policy	3.56	1.26	12
Lack of training on AI usage	3.02	1.43	13

Table 3 shows that the highest-ranked challenge experienced with the use of AI in construction project communications was “Lack of transparency due to its complexity” with a mean of 4.12 and a standard deviation of 1.17. This implies that this challenge was frequently implemented in the use of AI in construction project communication. Respondents showed that they were inhibited from fully adopting

AI technologies due to lack of transparency. All the other 12 challenges had mean ratings from 3.02 to 3.96 indicating that these challenges were frequently experienced.

Further the study analysed the correlation between implementation of AI tools and challenges experienced in the use of AI in construction project communication. A correlation of 0.601483 was obtained and this entails that an increase in usage of AI tools results in a moderate positive increase in the challenges identified in this study. The AI tools in use are causing a moderate increase in the challenges experienced in using AI in construction project communication.

Discussion

The study found that the respondents are knowledgeable about AI though its implementation is still low. In addition, the study also found that the AI tools highly used for enhancing construction project communication were image and video analysis. The findings of this study are in line with the findings of Dash and Sharma (2022), who found that most managing teams highly ranked image and video analysis AI tools, as this will make accessing the progress on-site remotely, thereby saving time and resources in traveling. Three other AI tools were moderately used although Collaborative Project Management Platforms were rarely used. These findings indicate low adoption of AI in construction project communication since effective project communication is catalysed by a platform where all project participants can commonly post their communications for easy information dissemination and sending. The results then corroborate with the findings of (Makaula, Munsamy and Telukdarie, 2021; Okereke, Muhammed and Eze, 2021) who also discovered a high awareness and low adoption of AI in the South African and Nigerian contexts respectively. This then challenges the Namibian's philosophy on AI adoption as a communication tool on construction projects. The high use of Image and Video analysis may be portrayed as the lowest level of AI adoption which can be witnessed at all levels of society.

AR and VR, Speech Recognition and Predictive Analysis were moderately utilised in project communication. Even though, these are significant AI tools (Smith, 2020; Kumar, 2021; Panda, 2023), their use to enhance effective communication can be limited where collaborative project platforms are not used as indicated in the previous paragraph. Tools offer the bare minimum requirements for multi-faced communication, a characteristic existent in construction due to the high number of team players. Hence, these results partly corroborate the views of Panda (2023) and Gamil and Rahma (2022) which signifies the capability of these tools to disseminate real-time data in physical and imagery form to the construction stakeholders. Whilst the use of AI in construction project communication can be appreciated, results indicate that the level of implementation may not be desirable. Based on the findings of this study, it can be concluded that many professionals in the Namibian construction industry are familiar with AI tools effective in project reporting than decision-making analytics. Thus, the Namibian construction industry should engage in processes that enable digitalisation adoption in decision-making to ensure project success (McManamy, 2021; Louw, 2022).

This study found out that the most prominent challenge being experienced in AI usage in construction project communication is a lack of transparency due to its complexity. Transparency in communication is important as it increases the credibility and reliability of data/information being sent or received. Thus, according to Wamba-Taguimdje, (2020), lack of transparency in AI communication diminishes user trust in AI systems leading to skepticism and reluctance to adopt or rely on AI technologies. However, this finding deviates from the barriers to communication that were cited by (Senaratne and Ruwanpura, 2016).

Other several challenges experienced in AI use were identified as lack of full information, unclear document management policy and lack of training on AI usage. AI use in project communication is a complex technology requiring quality data and skilled personnel having full knowledge of using it to extract, disseminate and make sense of data. Senaratne and Ruwanpura, (2016) also found out that construction project communication is heavily affected by a lack of skilled workers. Hence a lack of skilled workers in AI communication is a major barrier to the utilisation of these technologies on construction sites. This study noted that fragmented communication channels pose communication breakdowns when other members are not connected to AI networks. Fragmented communication channels could emanate from a lack of internet connectivity or a lack of interest in engaging in collaborative communication channels. Similarly, Henry (2020) claims that communication is heavily influenced by cultural and contextual factors such as lack of connectivity. AI models trained on limited or biased data may not fully grasp these nuances, resulting in cultural insensitivity or miscommunication.

The study identified a moderate positive correlation between AI usage and challenges experienced in construction project communication. Consequently, the implementation of AI is associated with the identified challenges in construction project communication. This partly corroborates with Smith (2021) who posited that although AI is implemented to solve certain challenges, it also comes with challenges. Hence this study is of the position that address of the previously mentioned challenges is likely to result in higher adoption of AI.

Conclusion

This study aimed to investigate the implementation of Artificial Intelligence (AI) to enhance communication among construction project stakeholders in Namibia. This study can enhance construction project stakeholder communication utilising AI technologies in Namibia. Moreso, this study can help the construction industry players to fully understand the effect AI has on communication process and reap the benefits which includes improved project performance. Furthermore, this study will help the construction professional to have knowledge on how best they can implement AI in construction communication and enhance their tasks.

The study found a low extent in AI implementation in Namibia although respondents had a high awareness of AI as a communication mode. The highly ranked AI tool for construction project communication was image and video analysis. Other tools such as NLP, AR and VR were moderately in use in construction project communication. The study thus concludes a low usage of AI tools in construction project communications. Furthermore, it can be concluded that many professionals in Namibian construction industry are familiar with AI tools designed for reporting activities than decision making analytics. Lack of transparency was identified as the highly ranked challenge in AI use in construction project communication due to AI complexity. Other challenges experienced in the use of AI included a lack of quality data and AI expertise. A moderate positive correlation was obtained between challenges experienced in construction project communication and the use of AI tools. The study hence concludes that the address of challenges will likely increase the level of adoption of AI on construction projects.

The results of this study can be generalised to other contexts with caution due to the small sample size and contextual differences. The data was only collected in Khomas and Erongo regions of Namibia. Future research should focus on the perceptions of all construction stakeholders in regions of Namibia to obtain a holistic view of the extent of AI adoption in construction project communication in other contexts.

Recommendations

Stakeholders should develop mechanisms for the address of challenges experienced in the use of AI in construction project communication to enhance the level of adoption of AI. Construction professionals should also be trained on the proper use of AI including the promulgation of feasible strategies to reduce the fragmented communication platforms in use.

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Implementing Education 5.0 in the AEC Field: a Living Lab Approach Based on the Quintuple Helix Model

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Abstract

The global interest in pursuing sustainable development goals has led to various innovations in different industries. Undoubtedly, the Architecture, Engineering and Construction (AEC) field and technology are complementary in nature and have to grow hand in hand. Education 5.0 represents a paradigm shift in educational practices by seeking to achieve holistic learning by integrating emerging technologies, real-world applications and collaborating with industry stakeholders. In spite of the fact that there is a fair amount of literature on Education 5.0, limited research has been conducted on effective pedagogies for its implementation. Therefore, the current study explores the implementation of Education 5.0 using the living lab approach from a quintuple helix perspective. In this study, a narrative literature review was conducted using a conceptual analytical approach to assess the compatibility between Education 5.0 and living labs and its potential to guide this integration with the quintuple helix model. One limitation of the narrative method is its lack of systematic rigour compared to other methods. Living labs can provide an authentic and rich environment in which innovations, technologies, and viable solutions to societal problems can be developed and co-created. Based on the quintuple helix model, the study concludes that the living lab approach represents a paradigm shift in implementing Education 5.0 in the AEC field. Further, higher education institutions should prioritise the development of living lab environments to foster the collaboration and innovation essential to Education 5.0. This study offers insight into implementing Education 5.0 in the AEC field using the living lab concept that fosters innovative, collaborative, and sustainable educational practice approaches.

Keywords: Architecture, Engineering and Construction, Education 5.0, Living lab, Quintuple Helix Model.

Introduction

Parallel to the growing global interest in achieving sustainable development goals, various innovations have since been explored in different industries. Innovation within the built environment is sadly not advancing fast enough to achieve ambitious sustainability goals (Molinari et al., 2023). Undeniably, our lives are increasingly dominated by digital technologies, whether in our personal or professional spaces (Puolitaival and Kiroff, 2021). Awang, Taib, and Muda (2020) attribute this technological shift to the industrial revolution, which caused a major change in the economy. There is no doubt that Architecture, Engineering and Construction (AEC) field and technology are complementary in nature and have to grow hand in hand.

Digital technologies have been noted for their role in encouraging social networking and interactive, collaborative engagements, along with those affecting education (Mallik and Mallik, 2017). Consequently, education sector needs to be aligned with industrial and technological development for better outcomes and benefit (Alharbi, 2023). Higher Education Institutions (HEIs) can strategically serve as a competency development hub for skills that are needed to meet future job demands. Amir and Akhir (2023) argued the difficulties in comprehending technology and construction knowledge in HEIs, particularly when a traditional method of teaching and learning is the only option. As a technologically oriented generation, Generation-Z students prefer more hands-on learning and are actively involved in the learning process. This shortcoming on the teaching pedagogy is bound to affect the competency development in HEIs. In light of the constant changes and growing adoption of digital technologies, the

requirement for digital literacy is also continuously changing and increasing (Puolitaival and Kiroff, 2021).

On the other hand, Education 5.0 represents a paradigm shift in educational practices by seeking to achieve holistic learning through integrating emerging technologies, real-world applications as well as collaborating with industry stakeholders (Alharbi, 2023). As literature suggests a shift from traditional pedagogy to experiential learning approaches where students are active participants in the learning process (Dabaieh et al., 2018), implementing Education 5.0 has significant potential for enhancing competency development in the field of AEC. In light of this, the current study explores the implementation of Education 5.0 using living lab approach from a quintuple helix perspective. By adopting a helix model, which promotes a multidisciplinary approach, the study contributes to the ongoing debate on educational evolution, and capacity development that prepares future-ready workforces. Study objectives include 1) examining the characteristics of Education 5.0 and evaluating how they align with the needs of the AEC field; 2) examining the living lab concept and its compatibility with Education 5.0; and (3) determining whether the quintuple helix model could be used to implement education 5.0 through living labs in the AEC industry.

Literature Review

Evolution of education

It is unquestionable that learning aspiration has shaped societies since humanity evolved. As part of a continuous learning process, academic knowledge is aligned with competitive market demands using modern technologies (Alharbi, 2023). The educational revolutions are also evolving similar to the phases of industrial revolutions. Despite this, the adoption of new, transformational learning frameworks isn't as fast as industry transformation (Tan et al., 2018). With the advent of the digital age, the educational system has been influenced by digital advancements. From a quick glance at the history of pedagogy, it can be seen that classroom practices have barely changed over the years (Mallik and Mallik, 2017).

a) Industry 1.0 (1IR)

Starting from the Industry 1.0 (1IR) phase, water and steam were used to mechanise the production (Awang et al., 2020). A major characteristic of Industry 1.0 is the transition from hand work to machine work, the development of new iron production processes, the expansion of the textile industry, and the increasing use of steam power (Crafts, 2004). A similar trend in educational thinking and practice emerged in the industrial age when factory-based production expanded. Education 1.0 emerged as an educational practice that focuses on the instructivist approach involving 3Rs, thus receiving, responding and regurgitating (Tan et al., 2018). In this traditional teacher-centered approach, students listen ("receive") to the teacher, take notes, read the text and do ("respond") the same worksheets, and then "regurgitate" by taking similar assessments to determine their level of learning.

b) Industry 2.0 (2IR)

The second industrial revolution (2IR) is marked by the use of electric power and assembly lines to create mass production (Hussin, 2018). At this stage, having realised that instructivist approach is not effective, it became common practice for teachers to encourage their students to interact with each other and learning from each other to promote interactivity (Tan et al., 2018). This interaction between learners and activities consisted of 4Cs, which are communicating, contributing, collaborating and co-creating (Tan, et al., 2018). Thus, education 2.0 advocated an active learning approach that fosters critical thinking and gaining hands-on experiences to prepare for the future working world. Experiential learning is a good example that can be attributed of this approach. Technology began to enhance traditional approaches during this time, leading to the development of open educational resources like blogs and websites that facilitate collaboration and knowledge co-creation (Tan et al., 2018).

c) Industry 3.0 (3IR)

The digital revolution, characterised by the use of electronics and information technology to automate production happened during the third industrial revolution (3IR) (Hussin, 2018). This era saw a widespread adoption of computers and information technology in manufacturing and services. Quite

rightly, the education 3.0 provided the academic community with a baseline for further exploration and linking of computing tools and academic learning environments (Alharbi, 2023). Therefore, a technology platform is created, changing the role of the teacher to a facilitator. These technologies include interactive whiteboards, Learning Management Systems (LMS), amongst other. Also, Education 3.0 is more concerned with connecting individuals who share their knowledge in order to co-create new knowledge (Tan et al., 2018), focusing on 3Cs (connecting, collectives, curating). The notable difference between Education 3.0 and its predecessors is that students learn on their own initiative, not for the sake of formal recognition.

d) Industry 4.0 (4IR)

The fourth industrial revolution (4IR) represents a transition beyond the third industrial revolution, which blurred the lines between physical, digital, and biological worlds (Hussin, 2018). A number of new technologies such as artificial intelligence, robotics, the Internet of Things (IoT), and 3D printing are advancing exponentially at a rapid rate. As a result, they are dubbed disruptive technologies because there is no historical precedent for the beginning of the development. The advent of 4IR sparked the development of Education 4.0, which incorporated information, internet, and technology into the teaching and learning processes, making it possible for students to learn at any time in digital platforms (Awang et al., 2020). The emergent of Education 4.0 was necessitated by the need to address the 21st-century skills demands (Tan et al., 2018), focusing on creativity, collaboration, communication, and problem-solving through digital literacy.

e) Industry 5.0 (5IR)

A human-centered approach is also seen in Industry 5.0 as a way to address societal challenges and foster sustainable development (Lantada, 2022). Furthermore, Lantada (2022) argued that Society 5.0 represents a human-centered society that balances economic advancement with the resolution of social problems through the integration of cyber and physical spaces. Likewise, the evolution to Education 5.0 geared towards problem-solving through value creation and quality education that aligns to the sustainable development goals. Education 5.0 goes beyond technology development and application and brings ethics and humanism into its core (Lantada, 2022). Hence, the society should be at the center of the revolutionary process, as a fundamental pillar to build more resilient, cooperative, and flexible communities (Merino-Barbancho et al., 2023). As part of this approach, emerging technologies, industry partnerships, and real-world applications are combined to promote lifelong learning, innovation, and societal impact. For this reason, the purpose of the study is to develop a conceptual framework of implementing Education 5.0 in AEC field, using a living lab concept based on the quintuple helix model. The next section briefly explains the research method employed before introducing the living lab concept and subsequently a quintuple helix model.

Research Methodology

This research investigates the implementation of Education 5.0 in the AEC field using a living lab concept based on a helix model using a conceptual analytical approach. As defined by Fumer (2004), conceptual analysis is a technique that treats concepts as classes of objects, events, properties or relationships by defining their meaning precisely by identifying and specifying the conditions under which any entity or phenomenon is classified under them. Therefore, a precise exploration of key concepts relevant to this research was made possible through this approach.

To gather and synthesise relevant literature, a narrative literature review method was used whereby literature related to the Education 5.0, living labs approach and helix model were explored. According to Saunders, Lewis and Thornhill (2012), narrative inquiry is an account of an experience told sequentially, with related events linked in a way that conveys significance for the narrator and meaning to the researcher. The current study's interpretive and qualitative nature made narrative an appropriate strategy for achieving its research objective. The research was based on a variety of sources, including journals, conference proceedings, government documents, and reports. The use of a computer database made it easier to retrieve vast amounts of information more quickly (Ramdhani et al., 2014). Thus, search terms included AEC, Education 5.0, living lab and quintuple helix model.

Following the collection of relevant literature, thematic analysis was performed to identify and categorise recurring patterns related to the research objectives. This analysis highlighted several key themes, such

as the application of living lab concepts, and the role of the quintuple helix model in fostering collaboration amongst different stakeholders (university, industry, government, society and environment). The use of a narrative method was considered as one limitation during the research process as it lacks the systematic rigor compared to other methods.

Living lab concept

Essentially, living labs are a pedagogical approach that encourages use-driven open innovation within real-life settings, by which users can collaborate with multiple committed stakeholders at one or more locations in order to create innovative ideas, processes, or products within multidisciplinary settings (Callaghan and Herselman, 2015). In this case, collaborative stakeholders can be academics, government, industry, NGOs, amongst other. Thus, implementing this approach can result in improved processes and service delivery, new business models, products, and services, as well as a wider socioeconomic impact on participating communities (Callaghan and Herselman, 2015). Living labs emerged in the 1990s to promote innovation and development of ICT.

A fair amount of literature exists on the developments of Education 5.0. However, limited research has been conducted on the effective pedagogies employed to effectively implement Education 5.0, particularly in AEC field. Notably, literature suggests a shift from a traditional pedagogy to more experiential learning approaches where students are active participants in learning process (Dabaieh et al., 2018). Consequently, an experiential architectural course was launched as a pilot teaching and learning experience in a living lab experimentation environment (Dabaieh et al., 2018), and was proven to be successful.

The living labs concept can be seen as an evolution of the traditional teaching as they add an active interaction dimension (Molinari et al., 2023). Various schools of thought suggest that living labs can provide an authentic and rich environment in which innovations, technologies, and viable solutions to societal problems can be developed and co-created (Chapagain and Mikkelsen, 2023, Rogers et al., 2023). Living labs can also connect several agents (Universities with students and academics/teachers, local companies, governmental agencies, and citizens), share information through collaborative practices, and facilitate communication between participants and other agents (Esashika et al., 2023). Although finding solutions to real-life problems is central, Living Labs should be environments to create learning.

Moreover, Callaghan and Herselman (2015) noted that living labs provide an accessible and interdisciplinary environment where participants can explore and collaborate. In doing so, academia, industry, students, and other stakeholders can co-create new ideas and concepts that will enhance teaching and learning, as well as enhance skills to address challenges. Herewith below key areas for implementing Education 5.0 as suggested by Alharbi (2023). Consequently, the core values by Callaghan and Herselman (2015) are listed in respond to the suggested implementation key areas. From the below Table 1, one can deduce the compatibility of living lab approach to effectively implement Education 5.0.

Table 1: Education 5.0 key areas vs living lab core values

No.	Education 5.0	Living Lab
1	Focused learning to become a professional	It is user-driven
2	Improved and blended concept of personalised learning	Collaboration and co-creation involving real-life communities and multiple stakeholders.
3	Applying creative thinking for solving problems	Improves processes and new products that are replicable and sustainable
4	Developing value-based learning culture	Positive impact to the socioeconomic environment (capacity building, development, empowerment).

Quintuple helix model

Helix models of innovation, which emerged in the 1990s, expand the role of various stakeholders in a knowledge-based society by emphasising the expanded role of diverse stakeholders (Zakaria et al., 2023). The first model, which is referred to as Triple Helix, entails a triadic relationship between the university, industry and government in the knowledge society (Ranga and Etzkowitz, 2013). Triple Helix model advocates the prominent role played by the university, industry and government in promoting

economic development and innovation. In this regard, university ranks first due to its increased importance in technology transfer (Zakaria et al., 2023).

Subsequently, the Quadruple Helix Model emerged, adding the society as the forth actor. According to this model, the public participation is given a greater attention in the innovative process (Merino-Barbancho et al., 2023). With this approach, the involvement of "users" in the innovation process was given an increasing importance, which became crucial for the inclusivity of the process and its sustainability (Merino-Barbancho et al., 2022). The preceding models, however, were unclear about how each actor relates to the environment, thereby leading to the introduction of the Quintuple Helix Model.

A Quintuple Helix Model integrates the environment as one of its entities, promoting social ecology characteristics and natural interactions between actors and their contexts and surrounding areas, which improves innovation ecosystems (Merino-Barbancho, 2023). In total, Quintuple Helix Model comprises of university (academic), industry, government, society and environment. The significance of these five direct social systems for interaction and cooperation, as well as their mutual benefit, cannot be overstated. In fact, Merino-Barbancho et al. (2023) emphasised the involvement of the society as a whole in building a solid economy. Co-management of innovations can be achieved by placing the society at the center of solving complex challenges. The living lab approach is thus proposed by Merino-Barbancho et al. (2023), which integrates user-driven innovation, bringing together different roles to solve a particular issue. Below Figure 1 depicts a Quintuple Helix Model. Subsequently, each subsystem is also discussed.

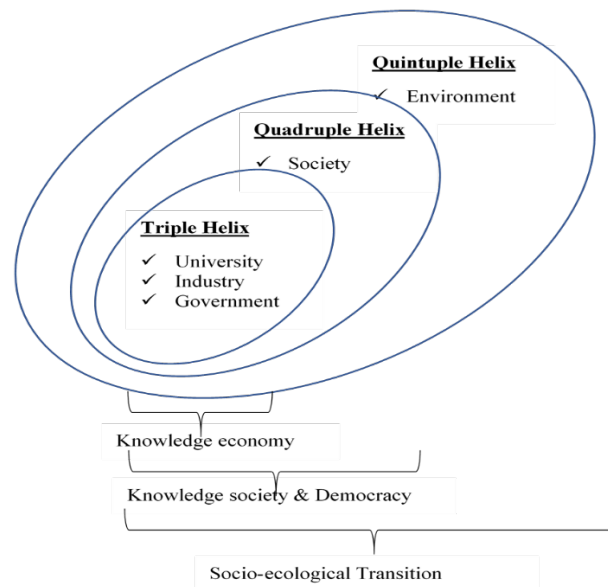


Figure 1: A quintuple helix model

a) University

Also referred to as the education system, academia and/or schools. The 'human capital' in this helix include students, lecturers, researchers and academic entrepreneurs. Jointly, these 'human capital' conducts research to create new knowledge and educate the workforce. The collaboration is fostered between academia, industry, government and society to apply research findings and solve real-life problems. Universities must be willing to fully embrace and adopt Education 5.0 through implementing effective pedagogical approaches like living labs concept.

b) Industry

This is the economic system helix, focusing on 'economic capital' like entrepreneurship, machines, products and technology amongst other. These are the key drivers of the economic growth through investing in new innovations and bringing products and services to the market. Industry collaborates

with academia to leverage on research advancements. For experience-based learning such as the living lab, it is important for the academia to collaborate with the industry.

c) Government

The significance of this helix is that it sets policies, regulations as well as providing funding for research and innovations. The willingness or political buy-in enables a conducive environment for investment, innovation and research. Without the endorsement from the government, any advancement toward implementing Education 5.0 will be futile.

d) Society

The forth subsystem, introduced as an addition to form quadruple helix, is 'social capital'. This helix represents a broader society's interests and values like traditions, value, etc. It ensures ethical considerations and advocates for inclusive and sustainable development through feedback on innovation processes. This is perfectly suitable to the core value of a living lab concept of positive impact to the socioeconomic environment, as previously alluded (Merino-Barbancho et al., 2023).

e) Environment

This last subsystem that completes the Quintuple Helix is decisive for a sustainable development and it provides people with a 'natural capital' like resources, plants, etc. (Carayannis et al., 2012). Collaboration and innovation can only be successful if stakeholders take into account environmental impacts and incorporate sustainability principles into their actions. As well, Shanika et al. (2022) suggested that existing construction education curriculum content should be redesigned and updated to prioritise sustainability-related knowledge.

Lessons learnt

The literature reviewed has shown the importance of embracing the digital transformation within AEC field, leading to the attainment of sustainable development goals. Particularly, Education 5.0 presents a more human-centric approach of learning through value creation that aligns to the SDGs. Traditional pedagogies are rendered ineffective at the present time, considering a great evolvement both in academia and the industry future skills requirements. As such, a living lab concept is regarded as a suitable approach that connects several agents (universities, industry, government, society and environment) to develop sustainable solutions to societal problems. The core values of the living labs concept seem to be comparable to the key areas of implementing Education 5.0, making this study's contribution even more valuable. In addition, adopting the Quintuple Helix Model for innovation further adds value through its emphasis on analytical understanding of all helices for continuous multidisciplinary involvement.

Conclusion

The study discussed the evolution of education, with emphasis on the implementation of Education 5.0 in the AEC field. The first objective was to examine the characteristics of Education 5.0 and evaluating how they align with the needs of the AEC fields. In a subsequent review of the literature pertaining to the living lab concept, it was discovered that Education 5.0 is highly relevant for addressing the evolving requirements of the AEC industry because it emphasises not only digitalisation and innovation, but also societal engagement and sustainability. Secondly, the study intended to assess the living lab concept and its compatibility with Education 5.0. findings suggested that the living labs are well-suited to foster the competencies and collaborative skills emphasised in Education 5.0. in line with the last objective, a conclusion can be drawn that the implementation of Education 5.0 in AEC field, through the living labs approach based on the quintuple helix model represents a transformative paradigm shift. In this approach, the environment is incorporated as one of its components, which promotes social ecology characteristics and natural interactions among actors and their contexts, improving innovation ecosystems. In addition, using a living labs approach will empower students with skills needed in the workplace and address real-world societal challenges. In this way, implementing Education 5.0 using living lab approach in the context of the quintuple helix model offers a promising route towards developing future-ready AEC graduates.

Recommendations

Several implications and recommendations have been derived from this study for policy, practice, and future research. Governments and educational institutions need to consider adopting policies that support the creation of living labs within universities and facilitate partnerships between academia and industry, which are critical for the effective implementation of Education 5.0. Living labs can significantly enhance the practical learning experiences of students in AEC through their integration into the educational framework. It is important for institutions to create collaborative spaces where students can collaborate with industry professionals to solve real-world problems in order to foster critical thinking, creativity, and adaptability while acquiring hands-on skills. Lastly, future research should examine the long-term effects of living labs on AEC education, especially in terms of student outcomes and their transition into the workplace.

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Leveraging Digital Technologies for Operations and Maintenance in Public Health Hospitals: The Case of KwaZulu-Natal

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Abstract

South Africa is preparing for the implementation of the National Health Insurance (NHI) to enhance universal health coverage. The hospital infrastructure's efficient operation and maintenance (O&M) is key to the NHI's success. However, many hospitals lack the reliable and accessible asset information necessary for effective O&M. This study investigates the use of digital technologies to enhance the O&M of public health hospitals in KwaZulu-Natal by exploring the use of digital technologies in the O&M process. A qualitative research methodology was adopted to comprehensively understand the phenomenon by exploring participants' experiences and perspectives. Nine respondents were purposively selected: Chief Executive Officers, Facilities and Maintenance Managers, and Quantity Surveyors with over five years of experience in hospital O&M. Semi-structured interviews were conducted using MS Teams and WhatsApp Video, and the data was thematically analysed. The qualitative approach was chosen to capture the depth and complexity of the respondents' insights regarding integrating digital technologies in resource-constrained environments. The study revealed that digital technologies could significantly reduce reliance on compensation budgets by automating processes and providing real-time data on critical hospital infrastructure components. These technologies were found to enhance O&M planning, optimise maintenance cost estimation, and align budgeting processes with actual O&M requirements. Notably, integrating such technologies will improve inventory management and performance measurement, directly impacting the operational efficiency of hospital services. This study is geographically limited to public hospitals in KwaZulu-Natal, South Africa, which may restrict the generalisability of the findings to other regions with different healthcare contexts and resource constraints. To realise the benefits of these digital technologies, budget allocation for their implementation must be prioritised over the Medium-Term Expenditure Framework (MTEF). Adopting these technologies could improve patient outcomes by minimising downtime, enhancing service reliability, and optimising resource use in hospital settings. By focusing on the specific challenges faced by public hospitals in KwaZulu-Natal, the research provides unique insights into the potential of digital solutions to transform O&M practices and improve healthcare delivery in similar environments.

Keywords: Asset Management, Facilities Management, Public Hospitals, Operations and Maintenance, Public Infrastructure.

Introduction

The South African public health system faces significant operational challenges that have eroded public trust in its ability to deliver quality care. For instance, the South African Institute of Civil Engineering (SAICE) reported in 2022 that the country's health infrastructure is below average, requiring urgent upgrades to avoid prolonged service downtimes that endanger public safety. In response to these systemic issues, the President of South Africa signed the National Health Insurance (NHI) Bill into law on 15 May 2024, aiming to enhance universal health coverage nationwide. However, this ambitious goal necessitates significant improvements in public health infrastructure. Kruk et al. (2018) emphasise that a robust infrastructure is essential for any effective health system. Despite these efforts, the state of South Africa's health facilities, particularly clinics and hospitals, have seen slight improvement since 2011, indicating a critical gap in the nation's health infrastructure management.

A 2021 report by the Public Service Commission (PSC) detailed numerous lapses in the operations and maintenance (O&M) of KwaZulu-Natal's public hospitals, including failures in air-conditioning systems, malfunctioning lifts, damp walls, and unhygienic public toilets. The PSC attributes these issues to inadequate budgeting and poor prioritisation of infrastructure maintenance, stressing the importance of reliable and timely data for informed O&M decision-making. Addressing these gaps requires understanding how digital technologies can enhance the availability and quality of O&M data in public hospitals. This study focuses on public health hospitals in KwaZulu-Natal, aiming to explore the role of digital solutions such as digital twinning, the Internet of Things (IoT), blockchain, and Artificial Intelligence (AI) in improving decision-making in O&M.

While there is a global trend toward developing "smart hospitals" that use digital tools for O&M enhancement, progress remains limited. Han et al. (2023) indicate that data availability and quality are critical components of this shift, with the need for diverse data sources, including both human expertise and digital input, to overcome current limitations. In South Africa, public hospitals face a unique challenge: they experience higher deterioration rates due to intensive use and constant operation of critical equipment (Schuman & Brent, 2005). This context heightens the need for comprehensive asset performance data to support sound O&M decisions.

For instance, the KwaZulu-Natal Department of Health allocated 27% of its total infrastructure budget to maintenance in 2018/19. However, by 2023/24, this had declined to 23%, reflecting a reduced emphasis on O&M. The decline highlights the urgency for strategies to optimise existing resources through digital technology, ultimately improving hospital functionality and patient care outcomes.

Although numerous digital solutions exist to generate and store asset information throughout the asset lifecycle, integrating or interfacing these systems remains challenging. Problems associated with the transfer of asset information from the construction phase to the O&M phase are not adequately addressed, resulting in poor data quality even in cases where Building Information Modelling (BIM) was used. As Lucas, Bulbul, and Thabet (2013) observe, facilities managers often incur unnecessary financial costs and expend considerable time due to poor-quality data that lack integrity and are not fit for use in maintenance planning and execution. Addressing these challenges is critical to improving decision-making and fostering a culture of maintenance that elevates the importance of O&M in public hospitals. Failure to resolve these issues will perpetuate the current state of immaturity in public hospital O&M, leading to continued service downtimes and further undermining the public health system.

Therefore, the aim of this study is to investigate the use of digital technologies to enhance the O&M of public health hospitals in KwaZulu-Natal by exploring the use of digital technologies in the O&M process and understanding the risks and disadvantages associated with digitisation of O&M processes in resource-constrained healthcare settings.

Literature Review

Operations and maintenance in perspective

Operations and maintenance (O&M) encompass the systematic processes and activities essential to ensuring that equipment, buildings, or constructed assets operate within their designed parameters throughout their lifecycle (Sapp, 2017). The O&M phase is the longest and most complex phase in the asset life cycle and requires the highest budget allocation compared to other asset life cycle phases (Ouertani, Parlikad & McFarlane, 2008; Chen & Tang, 2019). The costs incurred during the O&M phase constitute approximately 85% of the total cost of an infrastructure asset, and this phase is 15 to 25 times longer than the combined earlier phases of the asset lifecycle (Wetzel & Thabet, 2015).

O&M typically consists of three primary components: operations, preventive or planned maintenance, and corrective or unplanned maintenance. Effective operation of assets, coupled with robust risk management, enhances operational performance and reduces the asset lifecycle cost. However, while reducing lifecycle costs is essential, De Valence, Langston, and Best (2003) emphasise that cost reduction must not supersede the importance of value-adding strategies. As a result, organisations must implement effective operational strategies while ensuring planned and unplanned maintenance provisions.

Therefore, whilst the built asset is in use, effective operational strategies must be implemented, and provisions must be made for planned and unplanned maintenance. Planned maintenance focuses on pre-emptively preventing asset failure and mitigating potential downtime that could negatively impact operations (De Jonge & Scarf, 2020). Planned or preventive maintenance strategies include condition-based maintenance (CBM), predictive maintenance (PdM), reliability-centred maintenance (RCM), total productive maintenance (TPM), and risk-based maintenance (RBM). Unplanned maintenance, also known as corrective maintenance, occurs when an asset or system component is either on the verge of failure or has already failed, necessitating repairs or replacements to restore the asset to its operable condition (Erbiyik, 2022). While unplanned maintenance cannot be entirely avoided, particularly in the context of budget constraints and cultural challenges around maintenance, establishing planned maintenance systems can offer significant long-term value (Erbiyik, 2022).

In South Africa, the National Department of Health provides policy guidance for the management of capital projects over O&M. For instance, in 2015, the National Department of Health developed a Health Infrastructure Maintenance Strategy (HIMS) to introduce a standardised approach to infrastructure maintenance, yet the strategy was neither funded nor implemented. Similarly, a Ten-Year Infrastructure Plan for Health Facilities was developed with support from the Development Bank of Southern Africa (DBSA), calling for a deliberate focus on hospital maintenance. Despite the plan's recommendations—an estimated R2.12 billion annually for maintenance and R6.53 billion for refurbishing 30 hospitals in critical condition—these initiatives were also left unfunded and unimplemented.

Currently, there is no national maintenance policy to guide the prioritisation of maintenance in public hospitals and mitigate service disruptions. While the Project Management Information System (PMIS) exists at the national level, no national Computerised Maintenance Management System (CMMS) supports the O&M of public hospitals in South Africa. Similarly, the province of KwaZulu-Natal lacks its own CMMS. However, it has initiated the rollout of a web-based Health Infrastructure Portfolio System (HIPS) that allows provinces to upload high-level condition assessments and asset management data. However, this system does not function at the level of a CMMS.

Without a national policy on asset management for public health infrastructure, the KwaZulu-Natal Department of Health established its infrastructure asset management policy in 2021. This policy outlines the O&M strategies for infrastructure assets under its control. It specifies the minimum acceptable condition for various health service platforms. It identifies mission-critical installations that must remain operational to mitigate the risk of service delivery collapse and ensure building occupant safety. To meet the objectives of this policy, the department must implement a robust asset performance and condition monitoring system to facilitate maintenance planning for its hospitals.

Notably, the maintenance strategies outlined by the department lack a provision for predictive maintenance. Predictive maintenance, which modern organisations widely adopt, leverages tools such as sensors to collect real-time data from various components, machinery, and plant systems in hospital buildings. This data provides critical information for the O&M departments to carry out maintenance tasks before system failures occur, thereby preventing service disruptions (Sánchez-Barroso & Sanz-Calcedo, 2019; e Costa, Camero & Oliveira, 2012).

Predictive maintenance relies on digital technologies such as early warning systems, vibration monitoring, thermography, acoustic emission, oil and particle analysis, performance monitoring, and corrosion monitoring to assess the operational condition of mission-critical assets (Erbiyik, 2022; Costa *et al.*, 2012). Gallab, Ahidar, Zrira, and Ngote (2024) emphasise the importance of real-time data obtained through these tools. This allows organisations to determine the appropriate timing for maintenance actions, preventing asset failure and minimising negative impacts on healthcare services.

While the KwaZulu-Natal Department of Health conducts detailed condition-based visual assessments of its buildings, it is unclear how this condition-based information is used to prioritise maintenance activities. Commonly, organisations prioritise maintenance on buildings in the worst condition.

The role of digital technology in operations and maintenance

Advanced intelligent systems have been developed to provide real-time reliable information, assisting facilities and maintenance managers in making decisions that significantly reduce unplanned downtime and enhance organisational efficiency and effectiveness. These digital systems encompass artificial

intelligence (AI), big data analytics, digital twinning (DT), the Internet of Things (IoT), blockchain, cloud computing, robotics, augmented reality, and virtual reality (Gallab, *et al.*, 2024).

Artificial intelligence (AI) is extensively employed to predict failures in equipment or machinery by facilitating the sharing of data and analyses between operations and maintenance personnel and the machinery itself (Cardoso & Ferreira, 2020). Lee *et al.* (2020) note that AI utilises a machine learning approach, training algorithms on failure modes to enable predictions based on historical data and trends. Big data analytics entails the collection, storage, management, and efficient analysis of complex data to generate real-time information for addressing organisational needs, including monitoring, record-keeping, statutory compliance, process improvement, and trend analysis (Jan, *et al.*, 2019; Saranya & Asha, 2019). The complexity of data encompasses high variety, volume, and velocity, making traditional data management methods time-consuming and challenging. Big data analytics offers volumes of accurate historical and current data, generating patterns for efficient and effective decision-making across the organisation (Lee, Cao & Ng, 2017). This analytical approach supports predictive maintenance by ensuring that historical information is readily available for forecasting future trends. Big data sources include design data, asset operation data, staff behaviour data, staff working process videos, cost data, logistics data, environmental conditions, fault detection, product quality data, usage data, and customer information. This data is organised logically and integrated to support predictive maintenance management.

Despite the advantages of big data analytics, various concerns and challenges must be addressed to enhance the robustness and integrity of the data. These challenges include concerns regarding the reliability of raw data used for decision-making in big data analytics (Siddiqua, *et al.*, 2016), governance issues related to transparency and accountability (Siddiqua, *et al.*, 2016), increased risk of cyberattacks (Bertino & Ferrari, 2017) and the lack of sufficient knowledge regarding big data technologies and platforms among researchers and practitioners (Mohamed, *et al.*, 2020).

Another critical domain where big data analytics significantly impacts is the smart operations and maintenance of physical infrastructure, achieved by collecting and analysing data to enhance building management. This data may be structured, semi-structured, or unstructured, with over 80% of data utilised by organisations being unstructured (Das & Kumar, 2013). Data collection may involve various sources and technologies, including existing databases, Building Information Modelling (BIM), the Internet of Things (IoT), smart devices, Geographic Information Systems (GIS), sensory technologies, work orders, emails, and project reports (Cepa, *et al.*, 2023). Big data analytics technologies possess the capability to improve operations and maintenance performance in buildings.

Digital twinning serves as a valuable tool in predictive maintenance strategies (Gallab, *et al.*, 2024; van Dinter, Tekinerdogan, & Catal, 2023). A digital twin constitutes a digital model or representation of a building or machine, enabling operations and maintenance managers to access data remotely, conduct analyses, and make timely and informed decisions (van Dinter, *et al.*, 2023). In the context of a hospital, the model comprises design information alongside operational parameters. Sensors are strategically positioned to detect and provide near real-time diagnoses and prognoses regarding the health of the building and its installations. The digital twin delivers highly reliable information that facilitates timely decision-making. At the same time, the Internet of Things (IoT) allows for sharing of information among assets and devices within a common IoT network, enabling operational managers to make informed decisions based on the shared information (Yan, *et al.*, 2017). The IoT plays a critical role in condition monitoring, offering timely information accessible via digital devices over the internet (Cardoso & Ferreira, 2020).

Blockchain technology enables secure and centralised data storage while preserving relevant asset history, although it may not effectively manage large, complex datasets (Alabadi & Habbal, 2023). Additionally, blockchain facilitates the secure storage of smart contracts between contracted parties (Kumar, *et al.*, 2023). Cloud computing pertains to the physical storage and processing of data in the cloud, proving most effective when used in conjunction with IoT to manage data (Sadeeq, *et al.*, 2021). Augmented reality plays a significant role in O&M by providing real-time information about assets such as lifts and HVAC systems, while virtual reality can facilitate maintenance training through scenario simulations.

Digital technologies significantly enhance inventory management, particularly when integrated with just-in-time concepts and predictive maintenance strategies. These advancements enable the timely

availability of spare parts while avoiding cash flow constraints associated with holding excessive quantities of spare parts and materials (Hu & Boylan, 2018).

Ultimately, operations are hampered by the absence of digital systems integrating clinical and operational information, such as patient safety incidents, with physical building information (Lucas, *et al.*, 2013). Therefore, it is imperative to explore effective interface management between operational information and maintenance information to ensure the overall health and safety of patients, staff, and visitors within public health hospitals.

Challenges of digital technology in operations and maintenance

The operations and maintenance (O&M) phase is frequently impeded by various challenges that frustrate facilities and maintenance managers in their efforts to maintain operational efficiency. Despite many organisations experiencing insufficient funding for O&M activities, it is crucial for O&M managers to concentrate on mitigating obstacles that prevent the maximisation of value within the constraints of limited resources. A significant challenge encountered by O&M managers is the scarcity of reliable asset data or information. Many organisations lack essential asset portfolio information, leading to inefficient maintenance decisions and a consequent waste of financial and human resources (Dejaco, Cecconi, & Maltese, 2017). The availability of accurate, comprehensive, and accessible information regarding the infrastructure asset portfolio enhances decision-making processes and reduces maintenance costs (Ouertani, *et al.*, 2008; Dejaco, *et al.*, 2017).

Several challenges arise in the management of asset information. Some organisations rely on paper-based systems or Excel spreadsheets, while others utilise digital web-based systems to store asset information (Ouertani, *et al.*, 2008). Manual systems are often inefficient and fail to ensure effectiveness and efficiency in data integrity, retrieval, security, and analysis, ultimately preventing organisations from optimising the performance of their built assets and generating substantial organisational value (Demian & Walters, 2014). In contrast, digital systems provide necessary efficiencies in retrieving, analysing, and applying information, facilitating timely and informed decision-making. However, it is essential to avoid information overload, as excessive data can waste time and resources, leading to inefficiencies and adverse health outcomes (Shah, Hussain, Saddiq, & Yar, 2021). Furthermore, challenges related to conserving digital information must be addressed to ensure effective system maintenance, continuous access to data, and the prevention of damage to stored information, which may compromise its accuracy and reliability (Shah, *et al.*, 2021).

Research Methodology and Method

This study utilised a qualitative research methodology, which is well-suited for exploring complex and context-specific phenomena in depth. The choice of a qualitative approach was informed by its capacity to provide rich, detailed insights into participants' experiences, attitudes, and behaviours, offering a comprehensive understanding of the issues under investigation (Tenny, Brannan, & Brannan, 2017). This approach is particularly relevant in settings where the aim is to understand the nuanced dynamics of human experiences and decision-making processes, as it allows for the exploration of subjective meanings and interpretations (Saunders, Lewis & Thornhill, 2020).

Semi-structured interviews were selected as the primary data collection method. This choice was made because semi-structured interviews provide a balance between structure and flexibility, enabling researchers to probe for deeper insights while allowing participants the freedom to express their views fully. The interview schedule was developed based on a thorough review of the literature and preliminary consultations with experts in the field, ensuring that the questions were both relevant and capable of eliciting meaningful responses related to the research objectives.

A purposive sampling strategy was employed to select participants. This method was chosen to include individuals with the most relevant experience and insights, such as Chief Executive Officers, Facilities and Maintenance Managers, and Quantity Surveyors involved in hospital infrastructure operations and maintenance. The criteria for selection included a minimum of five years of professional experience in hospital infrastructure management. Nine interviews were conducted, and the ninth interview reached data saturation, as no new themes or insights emerged, affirming the comprehensiveness of the data collected.

Thematic analysis was used to analyse the interview data systematically. The process began with initial coding, where data segments were labelled based on their relevance to the research questions. These codes were then grouped into broader themes through an iterative process that involved comparing and refining patterns. This approach ensured a structured and rigorous analysis while preserving the depth and richness of the participants' narratives. Themes were further reviewed and refined to align with the study's objectives and to ensure they captured the core aspects of participants' experiences and perceptions.

In terms of data collection, eight interviews were conducted via Microsoft Teams, and one interview was conducted using WhatsApp video technology due to connectivity issues with MS Teams. This adaptation demonstrates the flexibility inherent in qualitative research, as it accommodates different circumstances to maintain the consistency and quality of data collection. Leveraging these digital tools also ensured inclusivity, enabling all selected participants to engage fully, regardless of technological constraints.

This methodology not only supports a comprehensive understanding of the phenomenon but also demonstrates adaptability and rigour, essential for generating valid and reliable insights that can inform practice and policy in the field of hospital infrastructure management.

Research Results

The demographic profile of the nine respondents in this study reflected a diverse range of professional experiences and positions. The respondents were between the ages of 40 and 62, representing a mature cohort likely to possess substantial expertise and experience in their respective fields. Six respondents were employed in hospital settings, while the remaining three worked at infrastructure management hubs, thus providing a balanced perspective from operational and strategic management environments.

Gender representation in the sample was limited, with only two female respondents, underscoring the gender imbalance commonly observed in the infrastructure and facilities management sectors. The professional roles of the participants included two Hospital CEOs, two Hospital Facilities Managers, two Hospital Engineers, three Infrastructure Management Hub Engineers, and one Quantity Surveyor. This range of roles offered insights from leadership and technical positions, ensuring that the data captured reflected a broad spectrum of operational and managerial challenges.

The data collected from the interviews were systematically analysed using thematic analysis. Four primary themes emerged from the analysis, each addressing key aspects of the research inquiry. This thematic structure provided a coherent framework for interpreting the responses, enabling a comprehensive exploration of the complex dynamics of infrastructure management and operations within the healthcare sector.

The inclusion of respondents from both hospital and infrastructure management settings, alongside varied roles such as engineers and senior executives, enriched the data by incorporating both macro-level strategic perspectives and micro-level operational insights. Such diversity in the sample enhances the study's validity and ensures that the findings are relevant to multiple facets of infrastructure management in healthcare.

Current O&M strategies

The first theme focused on understanding the existing O&M strategies used within hospitals in KwaZulu-Natal. The predominant maintenance strategies identified by all respondents within their organisations were preventive and corrective maintenance, consistent with the department's policy. Engineering personnel elaborated on specific strategies for their plant and equipment, such as time-based and condition-based maintenance. Time-based maintenance was predominantly implemented for aged, mission-critical equipment where reliability assessments were challenging. Respondent 2 stated, "*We focus on time-based maintenance for older systems because their reliability is difficult to predict.*"

On the other hand, condition-based maintenance was selectively used, depending on the condition assessments conducted by the infrastructure personnel from the head office or regional management hubs. Resource constraints were repeatedly cited as a barrier. Respondent 3 explained, "*We often lack*

enough personnel, so most of our efforts are spent fixing things that have already broken down." This finding is consistent with Gallab et al. (2024), who emphasised the limitations of predictive actions when real-time data is unavailable. The study also revealed that while some hospitals with experienced staff managed to proactively detect issues like leaks or temperature fluctuations, this was not widespread. Schuman and Brent (2005) have similarly noted the negative impact of limited asset performance data on maintenance planning.

A notable limitation across hospitals was resource constraints, where skilled personnel often found themselves occupied with immediate corrective support for hospitals, limiting their capacity to engage in preventive or predictive maintenance. This challenge echoes the findings by Gallab et al. (2024), who reported that predictive actions are frequently unfeasible without the availability of real-time monitoring tools essential for timely intervention.

Respondents highlighted that predictive or proactive maintenance was rarely implemented due to the unavailability of essential tools, technologies, and skilled personnel. The limited instances where predictive maintenance was applied depended on asset health data gathered from equipment reports, inspections, testing, and checks. For example, experienced personnel at some hospitals could detect leaks, vibrations, noise, and temperature anomalies through routine daily checks, allowing for early intervention. However, this proactive approach was limited to hospitals with access to skilled resources, particularly in electrical and mechanical installations. Respondent 6 stated, *"We rely heavily on our team's expertise; without their skills, it would be difficult to manage maintenance effectively."*

At specific installations like transformers, diagnostic techniques such as thermography were used to evaluate equipment health and implement predictive measures when necessary. This approach, supported by Erbiyik (2022) and de Costa et al. (2012), provides early warning signals for timely intervention, thus preventing failures. However, respondents reported that hospitals often engaged Original Equipment Manufacturers (OEMs), their agents, or contractors to perform periodic servicing of mission-critical installations, generating service reports indicating necessary further actions. Yet, delays in procurement processes hindered timely implementation, resulting in additional breakdowns. This aligns with Schuman and Brent (2005), who highlighted that limited access to asset performance data can negatively impact effective maintenance planning and execution.

A key issue raised by respondents was the lack of reliable asset data, impeding the development of maintenance plans that align with hospitals' operational needs. Respondent 3 explained, *"We lack the necessary data for our maintenance plans, making it challenging to prepare for future needs."* This finding underscores Schuman and Brent's (2005) argument regarding the adverse effects of insufficient asset information on strategic planning.

Awareness of digital technologies

The second theme addressed the second aim of assessing the awareness and implementation of digital technologies among hospital staff. Six respondents demonstrated familiarity with digital technologies such as IoT, AI, BIM, and monitoring sensors. Several respondents cited their use of digital technologies in previous roles, mentioning systems such as Supervisory Control and Data Acquisition (SCADA), Building Management System (BMS), and SAP. However, they acknowledged that their current employer lagged behind the private sector in adopting these technologies. Respondent 8 noted, *"In my previous job, we used a BMS system, but here, we are still stuck with paper files and Excel."* Respondent 1 mentioned, *"The asset information here is still on hard-copy files and Excel sheets, which is quite outdated."* This reliance on manual systems is consistent with Demian and Walters (2014), who observed that manual processes fail to optimise built assets' performance.

While respondents were aware of the potential benefits, they expressed frustration with the current manual processes, noting inefficiencies like spending hours searching for historical data during emergencies. The reliance on hard-copy files and Excel spreadsheets hindered effective planning and response times. This sentiment is reflected in the literature, as Lucas et al. (2013) argued that the absence of integrated digital systems linking clinical and physical infrastructure data undermines cohesive O&M strategies.

Respondents expressed frustration over inefficiencies tied to paper-based files and standalone spreadsheets, particularly the time-consuming nature of retrieving historical information needed for

emergency maintenance. For example, Respondent 4 shared, *"Sometimes it takes days to find contractor details for repairs, which could have been done instantly with a digital system."* In addition, respondents highlighted the lack of access to as-built drawings, which presented significant challenges when troubleshooting. They noted that the absence of integrated clinical and maintenance data further complicated efforts to make well-informed O&M decisions. Respondent 7 emphasised, *"We rely on clinical data that isn't connected to maintenance information, which makes decision-making harder."* This aligns with Lucas et al. (2013), who argued that disjointed systems undermine cohesive O&M strategies.

Furthermore, respondents highlighted the challenges related to inventory management. Although hospitals were expected to maintain a spare parts inventory, most respondents (six out of nine) indicated that this goal was often unachievable due to limited visibility into stock levels. They cited the lack of a digital system to provide real-time updates on inventory, which resulted in inefficiencies such as overstocking or holding surplus parts that could be better utilised elsewhere. These inefficiencies, as supported by Hu et al. (2018), led to prolonged equipment downtime and increased service disruptions.

Benefits of digital migration

The third theme explored the perceived benefits of transitioning to digital systems for O&M. All respondents agreed that shifting to digital platforms would enhance hospital operations, particularly through real-time monitoring. For example, Respondent 5 explained, *"With digital monitoring, we could see real-time data and manage our resources better."* Respondent 9 explained, *"With digital systems, we could monitor our substations remotely and act before issues escalate."* They stressed that incorporating technologies like monitoring sensors and cameras would reduce the need for frequent manual inspections and provide accurate trend analyses, enabling informed decision-making. This view aligns with Jan et al. (2019) and Saranya and Asha (2019), who emphasised the value of big data analytics for trend analysis in O&M decision-making.

Respondents also believed that digital technologies, such as AI and IoT, would enable them to predict equipment failures and implement proactive interventions to mitigate these failures. Additionally, digitalisation would streamline access to and analysis of asset history and reports. Accurate records of equipment age, historical repairs, condition assessments (such as degradation), and historical costs would significantly improve maintenance planning and decision-making regarding component and system replacement. Respondents responsible for budget and patient management emphasised that adopting digital technologies would reduce operating costs, patient safety incidents, and service interruptions. They also cited benefits such as increased convenience, reduced time spent searching for information, improved productivity, and enhanced communication.

Additionally, respondents highlighted the advantages of integrating digital systems for inventory management. One said, *"With digital systems, we could know exactly what spare parts we have on hand and avoid unnecessary downtime."* This view is supported by Hu et al. (2018), who identified that poor inventory management leads to extended equipment downtime.

Regarding emergency repairs, respondents noted that the speed of restoring systems to operating conditions would increase significantly with digitalisation. Respondents also highlighted that digital tools could enable predictive maintenance by monitoring equipment health and predicting failures, allowing for proactive interventions. The integration of AI and IoT, in particular, was seen as a means to simplify monitoring and facilitate remote operation. This would improve asset history and maintenance record management, which is currently time-consuming. Respondent 5 commented, *"Finding the right people with the asset information is difficult. A digital system could streamline this process and make data more accessible."*

Respondent 7 also mentioned that *"it takes considerable time to locate a contractor who met the work requirements using paper-based files, further delaying emergency repairs not covered by period contracts. Even in cases where the defect had been repaired under a period contract, comparing service providers was time-consuming."* Respondents also noted that sometimes a defect had been repaired by a contractor within the past year and was still under warranty. However, without a digital system to track such records, it was difficult to take advantage of warranty coverage. These inventory management challenges are consistent with findings by Hu et al. (2018).

Considerations, risks, constraints, and disadvantages

The final research question examined the constraints and risks of adopting digital technologies in hospital O&M. Respondents acknowledged several considerations for a successful digital transition in hospitals, including documenting current processes, aligning them with human resources, and addressing legal and financial requirements. They emphasised that change management is critical, particularly given the varying organisational cultures between older and newer hospitals. Respondent 1 noted, *"We need to approach this change thoughtfully to accommodate our diverse staff."*

Several respondents mentioned needing a well-documented transition plan aligning with current human resource structures, roles, and legal requirements. Concerns about the "garbage-in, garbage-out" phenomenon were prevalent, emphasising the need for tailored training programmes. Respondent 9 warned, *"If we don't input the correct information, the system will only generate poor outcomes."*

Connectivity issues emerged as a significant concern, particularly in rural hospitals. Respondents stressed that the existing network's limited bandwidth and reliability were major risks, as digital systems require robust support. They recommended exploring alternative networks, including cloud storage, to enhance system availability. Respondent 4 expressed, *"Without reliable IT support, these systems could fail when needed most."* Respondents from rural hospitals highlighted network unreliability, stating, *"Our current network struggles with bandwidth; implementing digital systems will be difficult without improving this."* These concerns align with the findings by Bertino and Ferrari (2017), who discussed the challenges of safeguarding internet-based data. Further, budget constraints were seen as a major limitation, with respondents pointing out that the Department often struggles to procure even basic IT equipment.

Cybersecurity risks were also a prominent concern. Respondents noted that digital systems are vulnerable to hacking and sabotage, as Bertino and Ferrari (2017) highlighted the challenges of safeguarding data collected, stored, and processed through internet systems. These risks, if not properly mitigated, could pose a serious threat to the safety of patients and staff. Furthermore, respondents pointed out that the Department and government as a whole face budget constraints, with many vacated posts remaining unfilled due to cost containment measures. This could limit the sustainability of operating a digital system, as delays or failures in filling key positions could hinder the maintenance and analysis of digital data. Additionally, respondents noted that if a post is eventually filled, there might not be a budget to train the new hire or provide them with the necessary tools.

Training emerged as another critical factor. Respondents underscored the importance of equipping staff with the knowledge and skills to operate digital systems effectively, ensuring accurate data input and decision-making. Respondent 2 explained, *"Training is essential to prevent mistakes that could affect hospital operations."*

Conclusions

This study aimed to explore the current state of O&M strategies in public hospitals, assess the awareness and use of digital technologies, and identify the benefits, risks, and constraints associated with digital transformation. The findings reveal a clear need for digitisation within hospital O&M processes to improve efficiency and reduce operational disruptions.

The findings demonstrate that while preventive and corrective maintenance practices are prevalent, there is limited implementation of predictive maintenance due to resource constraints and insufficient real-time monitoring tools. This highlights a gap that digital technologies could fill by enhancing equipment monitoring and enabling timely interventions.

Respondents showed varying levels of awareness with digital systems. However, the current reliance on manual systems and hard-copy files in hospitals impedes efficient decision-making. Transitioning to integrated digital platforms, which respondents recognised as beneficial, would streamline information access and reduce response times for emergency maintenance.

Respondents acknowledged the potential benefits of digitisation, such as real-time monitoring, automated data management, and improved asset history tracking. However, they also highlighted significant risks, including cybersecurity threats, connectivity challenges in rural areas, and budget

constraints. Addressing these barriers will require careful planning, adequate resource allocation, and comprehensive staff training to build capacity and manage change effectively.

Overall, the study underscores that successful digital transformation in hospital O&M hinges not just on technological investment but also on aligning these efforts with existing business processes, building organisational readiness, and engaging all stakeholders in a sustained manner. To maximise the potential benefits, hospitals must proactively manage risks, secure necessary funding, and ensure continuous capacity-building.

Recommendations

To successfully guide the digitisation of operations and maintenance (O&M) processes in hospitals, the following recommendations are directly tied to the study's conclusions.

A dedicated and sufficient budget should be allocated for implementing and maintaining digital systems. This budget must cover electronic devices (e.g., computers, tablets), software licenses, cloud storage, and ongoing maintenance. To ensure financial sustainability, the Department should also explore leasing options for equipment and cloud services to reduce upfront costs and mitigate delays in device repairs.

The Department should invest in upgrading its network infrastructure. This includes expanding bandwidth, particularly for rural hospitals, and integrating alternative solutions such as cloud storage to improve system reliability. A phased implementation plan should be developed, with timelines indicating short-term upgrades for high-priority hospitals and longer-term goals for comprehensive provincial coverage.

A key challenge is staff unfamiliarity with digital technologies. To address this, the Department needs to develop a digital literacy training curriculum tailored to the specific functionalities of the new O&M systems. This should be an ongoing programme, ensuring continuous capacity-building, and incorporating refresher courses to accommodate staff turnover.

The Department must invest in robust cybersecurity infrastructure. This should include training for IT staff on advanced security protocols, implementing multi-factor authentication for access to digital systems, and ensuring compliance with relevant data protection regulations. A timeline for deploying these measures must coincide with the system rollout phases, ensuring that security protocols are in place as soon as the digital systems are operational.

By adopting these recommendations with an assertive and phased implementation approach, the Department of Health can overcome the identified challenges, thus enhancing the efficiency of O&M processes, reducing costs, and improving service delivery across healthcare facilities. This will improve operational efficiency, reduce costs, and enhance patient safety and service delivery across the healthcare system.

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Micro Quantity Surveying Enterprise Growth Stage Model: a South African Perspective

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Abstract

As businesses expand and evolve, their focus naturally shifts towards enhancing efficiency, lowering costs, and improving customer satisfaction. Growth stage models (GSM) are essential for micro-QS enterprises to understand their market position, develop growth strategies, and forecast future movements. This study aims to delineate a GSM specifically for micro-QS startup enterprises within the unique South African built environment. This study adopted an emic epistemological inductive philosophical approach to comprehend the phenomena associated with the evolution of micro-QS enterprises in South Africa. "One-on-one" semi-structured interviews were conducted with micro-QS enterprise owners. The conversations were recorded, documented, and the findings were summarised. Unique circumstances, world views, and perspectives necessitated a qualitative narrative and content analysis. The literature review and interviews revealed that micro-QS enterprises face unique external environmental challenges that directly impact their growth. While the literature suggests four to six growth stages for startup businesses, it was found that micro-QS enterprises might experience only three growth stages: initial growth, consolidated growth, and maturity. The study realised that growth stages are not linear and can vary significantly based on external factors, personal decisions, and the broader economic environment. The study concludes that micro-QS enterprises in South Africa operate in a highly volatile environment, requiring adaptability, strong professional networks, and a balance between personal and professional goals. The scope of this study is limited to micro quantity surveying enterprises in South Africa in 2024. It is also subject to the limitations of the research design, particularly concerning the responses from the interviewees. This study enhances operational business intelligence for micro-QS enterprises regarding situational awareness, management, predictions, and planning. Growth stage knowledge adds value to public and private stakeholders in the South African built environment. Identifying a GSM for micro-QS enterprises is unique in South Africa and fills a valuable gap in tracking development from startup to maturity.

Keywords: Micro Quantity Surveying Enterprises, Growth Stage Model, Maturity Model, Quantity Surveying.

Introduction

- *"But here we may read a lesson from the young trees of the forest as they struggle upwards through the benumbing shade of their older rivals"*
- (Marshall, 1890)

As businesses navigate the complexities of growth and competition, particularly in the context of micro quantity surveying (micro-QS) enterprises in South Africa, understanding the dynamics of their operational environment becomes crucial.

Over 95% of businesses in South Africa are classified as Small, Medium, and Micro Enterprises (SMMEs), employing 87% of the current workforce and projected to create 90% of the estimated 11 million jobs by 2030 (South Africa. National Planning Commission, 2013), (Small Enterprise

Development Agency, 2023). However, the alarming failure rates of these enterprises, with over 70% failing within the first five years (Bushe, 2019), underline the urgent need for robust frameworks to support their growth and sustainability. This is particularly pertinent for the construction industry, which, along with real estate and business services, contributes 12.7% to the national turnover (StatsSA, 2023).

In South Africa, 436 quantity surveying enterprises are registered with the Association of South African Quantity Surveyors (ASAQS) (Goorcharan, 2024). The number of micro quantity surveying practices (with fewer than 10 employees) and the failure rate of startup quantity surveying practices within their first five years of operation in South Africa are unknown (Goorcharan, 2024).

Startup quantity surveying enterprises should have a business plan and model. According to 'Business Theory' (Drucker, 1994), any practical business model should include growth guidelines, effectively functioning as a growth model that delineates various maturity levels. Consequently, it can also be construed as a maturity model. By understanding the stages of growth and the growth stage model, enterprises may make informed predictions for strategic management (Kurniati Bachtar et al., 2019). Theoretical studies emphasise the significance of growth, essential for sustaining business vitality, placing it at the forefront of small business and entrepreneurship research (Blackburn et al., 2013). By 2010, over 104 growth models had been identified (Wiklund et al., 2009a); however, Blackburn et al., (2013) note that many of these lack empirical robustness. Wiklund et al. (2009) criticise growth models for their failure to account for all variables that may influence small business growth, identifying five distinct "perspectives" on business growth, namely, entrepreneurial orientation, the environment, strategic fit, resources, and growth attitude. Business theories such as those pertaining to competitive advantage, as well as business model theories specifically applied to micro quantity surveying enterprises, constitute the secondary layer supporting the objectives of this study.

In theory, all micro quantity surveying enterprises are founded by ambitious, educated and trained registered quantity surveyors (Ashworth & Hogg, 2007), (ASAQS, 2014), who adhere to professional standards and common objectives such as ethics, profitability, job satisfaction, and professional advancement (ASAQS, 2014). These adjectives resemble the entrepreneurial, and growth attitude perspectives proposed by Blackburn et al., (2013). Sustainable growth requires a broader intelligence provided by growth stage models (Kurniati Bachtar et al., 2019).

The objectives of this study are to engage on a social constructivist approach with micro quantity surveying enterprises in South Africa seeking to understand the unique circumstances of their businesses and growth. The aim of the study is to establish a growth stage model (GSM) tailored for micro-QS startups, providing a framework to analyse their development from inception to maturity. The GSM is essential for these enterprises to enhance efficiency, reduce costs, and improve customer satisfaction, thereby positioning themselves effectively within the South African built environment.

The growth dynamics of micro quantity surveying enterprises in South Africa within an increasingly complex built environment remain largely unexplored (Goorcharan, 2024). Despite their crucial role, the evolution and maturation of South African startup quantity surveying enterprises have received scant academic attention over the past decade. There is a significant lack of standardised market intelligence for micro quantity surveying enterprises in South Africa. This gap has led to an impeding ability to manage growth effectively from startup to maturity. Enhanced market intelligence is crucial not only for the enterprises themselves but also for improving statutory regulation in South Africa, thereby supporting sustainable growth and development within the sector (Penrose, 2009). The central focus of this study is to identify commonalities in the maturation process of micro quantity surveying enterprises in South Africa.

This study will focus on micro quantity surveying enterprises' growth, evolution, and maturation processes as a foundation for developing a unique growth stage model.

The main research question for this paper is:

"What are the distinct phases of growth for micro quantity surveying enterprises in metropolitan areas over a five-year period?"

The reason for this question is to distinguish the growth phases of a micro-QS enterprise. In order to do this, the growth phases will have to be identified and described according to existing literature (Churchill & Lewis, 1983), (Roper, 1999), (Dobbs & Hamilton, 2007), (Wiklund et al., 2009b).

Literature Review

Business growth models

A business is somewhat similar to a living organism (Marshall, 1890) Business growth is comparable to infancy, childhood, adulthood, and maturity, where each new stage is marked by accomplishments, gaining experience, and achieving the goals set. Business growth is vital for a company's well-being as it opens possibilities to attract investment and talented professionals and serves as a primary indicator of a company's success (Kushnir, 2024).

- *"Growth is written into the culture of a business enterprise as the hallmark of its success" (Nieuwenhuizen & Nieman, 2019)*

Growth could be seen as one of the ultimate goals of an enterprise. From initiating the enterprise, a positive growth curve is essential for survival to accommodate an ever-evolving market. Nieuwenhuizen and Nieman (2019) describe the term growth an umbrella term accommodating processes like better products or services, improved infrastructure, more employees, greater management structure, increased turnover and higher status. Growth is regarded as invertedly to failure.

Small firm growth is a research area that has attracted considerable attention in recent years. Despite substantial increase in research volume, recent reviews of the literature on small firm growth suggest that little is still known about the phenomenon, and conceptual development has been limited. Davidsson and Wiklund (Davidsson & Wiklund, 2006) discuss the shortcomings in the field extensively. A major reason for these shortcomings, it is argued, is that this literature is highly fragmented— several theoretical perspectives have been developed, but there is little conversation between these perspectives. For example, a striking feature of reviews of studies of firm growth is that each study only covers a fraction of the variables considered important in other studies (Storey, 1994), (Wiklund et al., 2009b) (Storey & Greene, 2010).

Enterprise growth does not occur spontaneously; rather, it is the result of a strong desire to achieve specific goals. This ambition is often embodied in the founder's vision for the enterprise. Once the goals and vision are clearly articulated, a strategic plan must be developed to achieve these objectives using the available resources. The mission statement should be realistic and viable, taking into account the target market, competitors, and the external business environment. The business strategy supports the mission statement by providing direction for achieving short-term objectives. Essentially, the business strategy is a well-conceived plan designed to utilise the enterprise's resources optimally in order to achieve short-term objectives while keeping the ultimate goals in focus (Alfred P. Sloan, 2003), (Rosemann Michaeland vom Brocke, 2015), (Kristanti et al., 2019).

Wickham (2016) further believes that due to the multifaceted nature of organisations, the entrepreneur must constantly view the growth and development of a venture from four major business perspectives;

- a financial perspective,
- a strategic perspective,
- a structural perspective, and
- an organisational perspective.

Nieuwenhuizen and Niemand (2019) agrees with Wickham (2016) and explain that the four perspectives are interrelated to facilitate growth.

Strategic growth according to (Nieuwenhuizen & Nieman, 2019) refers to the "way the enterprise interacts with its environment". How the enterprise strategically position itself and interacts with its environment is an indicator of growth. Startup enterprises focus on survival and learn through experience to find their strengths and weaknesses to find their special niche in the market. Micro-QS enterprises might grow into a specialised niche market to become the leader in that area.

“Structure follow strategy” (Nieuwenhuizen & Nieman, 2019). Structural growth refers to the internal evolution of systems, procedures, communication channels, managerial roles and responsibilities, resource management, leadership, etc. The structure of the enterprise will adapt, evolve and grow as the strategic positioning of the enterprise adapt, evolve and grow. The structure of the enterprise will also be influenced by all the variables in the external environment which include the political atmosphere, the macro economy, climate change, etc.

Organisational growth refers to the size and layout of the enterprise. As the enterprise attract more work and generate higher profits the size and layout of the enterprise will adapt to accommodate the greater demands and manage the complexities associated with that. (Nieuwenhuizen & Nieman, 2019). The founder of the enterprise will rise higher in the echelons as the enterprise grow.

As the enterprise evolve strategically it will attract more clients and investors which will increase the income and afford the enterprise to make structural and organisational changes. These changes should make product delivery more effective and efficient to the benefit of its strategic positioning. Beneficial strategic positioning will in turn support financial growth (Nieuwenhuizen & Nieman, 2019).

Financial growth is measured by means of standard accepted financial parameters, such as;

- Increase in turnover
- Increase in total assets
- Increase in profit
- Increase in return on investment
- Increase in any other performance indicator

Nieuwenhuizen and Nieman (2019) identified five growth stages, (1) pre-start-up stage, (2) startup stage (infancy), (3) breakthrough or growth stage, (4) maturity stage, and (5) decline or rejuvenation stage. These stages of growth were first introduced by Greiner (1972) and then further developed by Churchill and Lewis (1983), and finally refined by Scott and Bruce (1987) to the model proposed by Nieuwenhuizen and Nieman (2019).

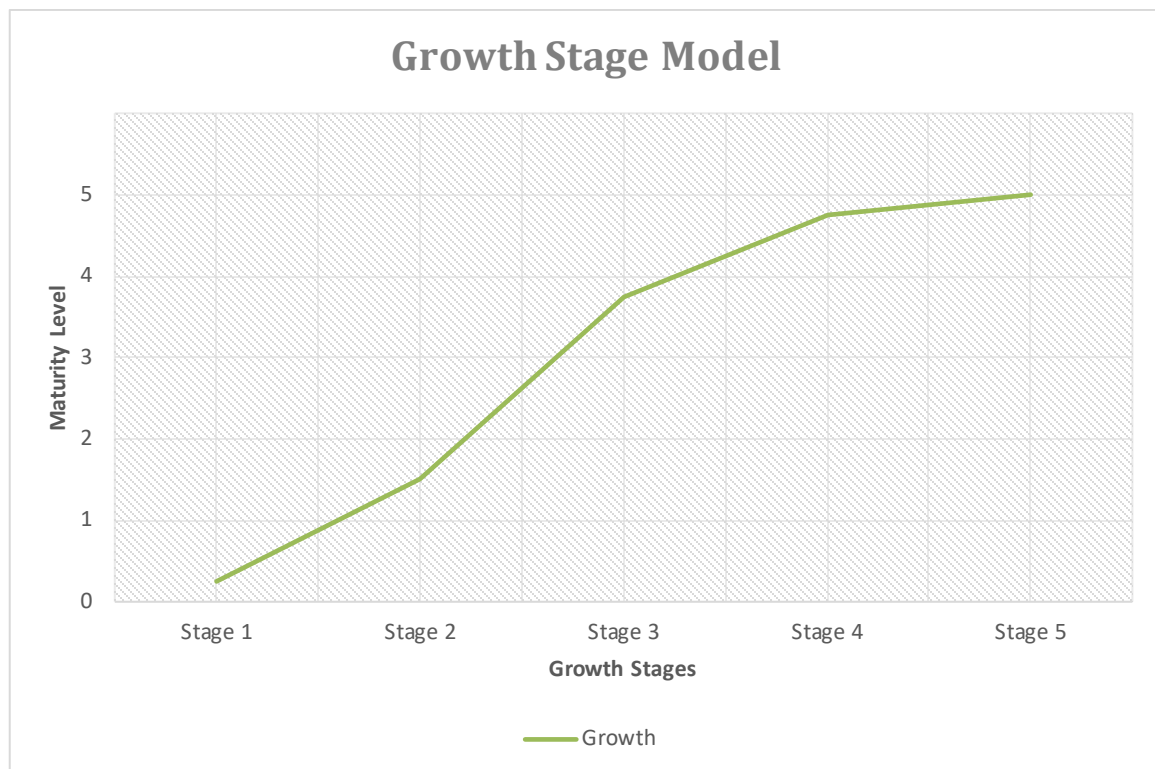


Figure 1: Typical growth stage model (Churchill & Lewis, 1983) (Wiklund et al., 2009a), (Kurniati Bachtiar et al., 2019).

Storey and Green (2010) added a final sixth stage to the growth model which accommodate for enterprises that decline after reaching maturity which is also incorporated into the business growth model of Nieuwenhuizen and Nieman (2019).

The rapid advances in technology and the business environment requires a revised and simplified growth model. Bachtiar and Amin (2019) highlight it that SMME's will not survive if they rely on outdated research which didn't took the Industrial Revolution 4.0, the Internet of Things, and Artificial Intelligence into consideration. They are of the view point that the lifespan of products and services are being shorten by technology and in many cases replace traditional services. It is argued that many SMME's will fail prior to reaching maturity by skipping the maturity stage and jumping from the growth state to the decline stage. The business environment is changing and so should the guidelines change. Bachtiar and Amin (2019) propose a growth stage model that only consist of three stages, (1) Startup, (2) Growth and Maturity, and (3) Decline.

Growth stage model applied to SMME quantity surveying enterprises

Micro quantity surveying enterprises are not exempt from growth stage models. The quantity surveying profession has the benefit of statutory regulations with minimum requirements for inaugurating a quantity surveying enterprise to the benefit of the public as well as the QS enterprise. Minimum requirements ensure that startup quantity surveying enterprises are initiated by highly educated and well-trained professionals.

According to the QS Act (Act 49 of 2000), the South African Council for the Quantity Surveying Profession (SACQSP) is responsible to issue an annual "Tarriff of Professional Fees Schedule". Hourly time charges for professional services delivered by professional registered quantity surveyors (PrQS's) are divided into three maturity categories,

- Not exceeding 5 years' experience
- Exceeding 5 years' experience and not exceeding 10 years' experience
- Exceeding 10 years' experience

This is not unique to the South African Quantity Surveying profession. The international accreditation society, "The Royal Institute of Chartered Surveyors (RICS)" has a similar tariff of professional fee schedule (Royal Institute of Chartered Surveyors, 2024) The RICS also divided the degree of maturity comparison into three categories with a difference in duration, as follows,

- Professional member under 2 years
- Professional member
- Fellow

It is evident that the profession recognises three growth stages for professional registered quantity surveyors. The smallest micro quantity surveying enterprise consist of a singular quantity surveyor (thus, the persona is the enterprise) and it is therefore suggested that the same growth stages should apply for micro quantity surveying enterprises.

In South Africa, most startup businesses are called "Micro Enterprises". According to the National Small Enterprise Act, 1996 (Act 102 of 1996) amended in 2019, all small, medium and micro enterprises are categorised according to their full time equivalent of paid employees, annual turnover, and distinct business sector. Enterprises in the SA construction sector is accordingly categorised into the following definitions.

Table 1: The South African definition of micro enterprises in the construction sector

Enterprise definition	Total full-time equivalent of paid employees	Total annual turnover
Micro	1 - 10	< R 10 million

Source: (Republic of South Africa, 2023)

Micro and small enterprises in South Africa contributed to 22% (R2,3 trillion) of the country's turnover in 2019 according to the 2019 Annual Financial Statistics (Department Statistics South Africa, 2020).

Small, micro and medium enterprises (SMME), are a catalyst for economic growth (Bushe, 2019) (DSBD & SA, 2023). It is concerning that the failure of SMMEs remained high for the past twenty years in South Africa, with a failure rate of more than 50% within the first five years of existence. This phenomenon is not unique to South Africa (Brink & Cant, 2003) and apply to all industries. In 2019, it was estimated that more than 70% of SMMEs failed within seven years of existence (Bushe, 2019) The Department of Small Business Development estimated the failure rate at 70% within five years (DSBD & SA, 2023).

Considering the 2015 SACQSP professional fee scales as they apply to micro quantity surveying enterprises, which are defined as having fewer than 10 employees and a turnover of less than R10 million in accordance with the National Small Enterprise Act, 1996 (Act 102 of 1996, as amended in 2019), the R10 million turnover threshold signifies the transition point at which micro enterprises enter a higher enterprise category. This financial threshold, therefore, represents the maturity level for micro enterprises. Given that the startup stage is positioned at the opposite end of the maturity stage, it can be inferred that the growth stage is situated between these two stages. By dividing the micro enterprise category into three equal stages, the startup stage, growth stage, and maturity stage are delineated. Each growth stage is characterised by specific entry and exit thresholds, as illustrated in Figure 2.

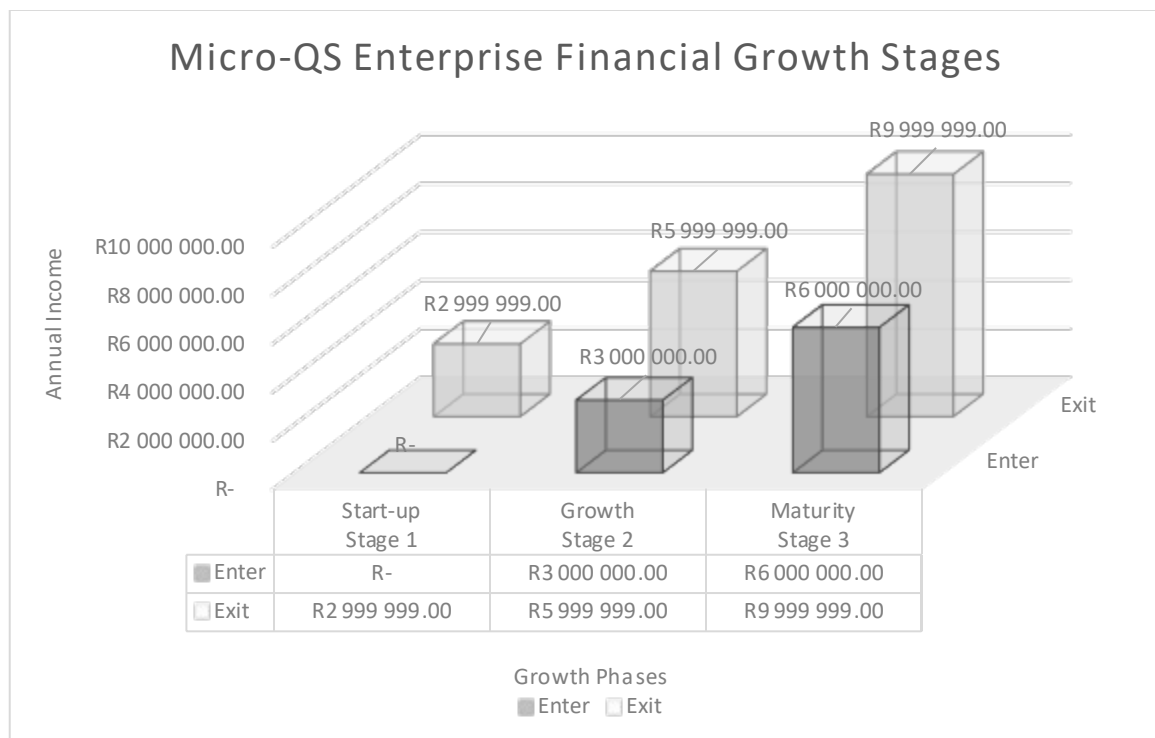


Figure 2: Micro-QS enterprise financial growth stages

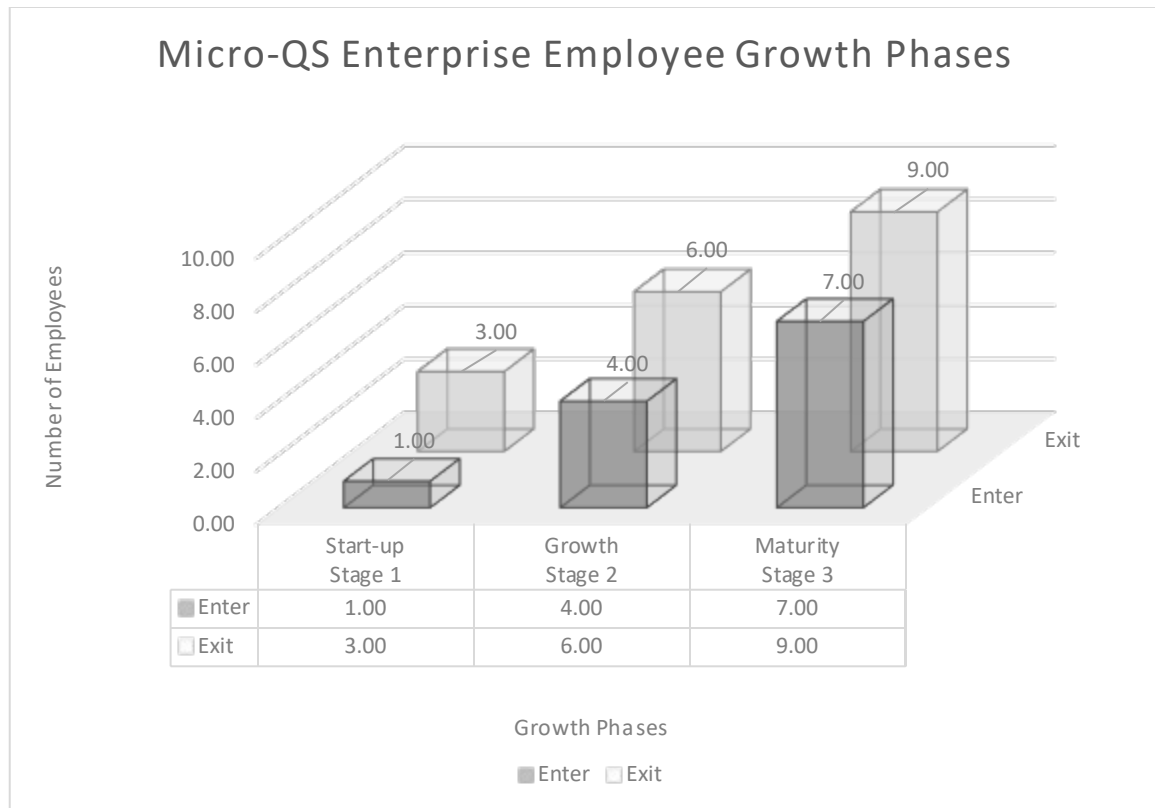


Figure 3: Micro-QS enterprise employee growth phases

As mentioned, the National Small Enterprise Act, 1996 (Act 102 of 1996, as amended in 2019), also stipulate a total full-time equivalent of less than 10 paid employees. This signifies the other threshold transition point at which micro enterprises enter a higher enterprise category. Similar to the financial threshold, this threshold also represents the maturity level for micro enterprises. Given that the startup stage has a minimum of one employee and maturity then has nine employees. Delineating the micro enterprise by dividing full-time equivalent employees into three equal stages, the startup stage, growth stage, and maturity stage. Each growth stage is characterised by specific entry and exit thresholds, as illustrated in Figure 3.

These financial and employee stages were used to categorise interviewees for this study.

The concept of growth for a QS enterprise warrants further discussion. As previously noted, growth is intrinsically linked to financial expansion. However, financial growth is underpinned by strategic, structural, and organisational development. The objectives of this study are to engage on a social constructivist approach with micro quantity surveying enterprises in South Africa seeking to understand the unique circumstances of their businesses and growth. The aim of the study is to establish a growth stage model (GSM) tailored for micro-QS startups, providing a framework to analyse their development from inception to maturity considering the unique parameters associated with each phase.

Within a relativist ontological framework, an infinite number of micro-QS enterprise growth scenarios may be envisaged, as each enterprise possesses a unique trajectory of growth. In its most basic form, a micro-QS enterprise might be established only to fail shortly thereafter for various reasons, without ever reaching any of the recognised growth stages. Conversely, another enterprise might rapidly advance through all growth stages, achieving maturity, which is characterised by a turnover exceeding R10 million per year and more than ten employees. A third scenario could involve an enterprise that gradually evolves over time, reaching maturity through accumulated experience but never surpassing the threshold that defines a micro enterprise. Many such enterprises prefer this operational approach and are satisfied with maintaining their status as a mature micro-QS enterprise. Another possibility is an enterprise that attains maturity but, due to various factors, reverts to the growth phase, thereby

oscillating between the growth and maturity stages. The final scenario may involve a combination of the aforementioned trajectories.

“What are the distinct growth phases of SA micro-QS enterprises in metropolitan areas over a 5-year period?”

It is suggested that a qualitative research approach is most appropriate for exploring the growth phenomenon of micro-QS enterprises. (Denzin & Lincoln, 2000).

Research Methodology

A qualitative narrative research method acknowledge that micro-QS SMMEs operate within a unique and constantly shifting natural and emotional landscapes, influenced by a multitude of real and social interactions. The study will rely on ontological subjective assumptions and inductive reasoning to successfully reach the objectives of the study (Chreswell & Chreswell, 2018).

The research will adopt a subjectivist approach, with a primary focus on qualitative narrative content analysis. The current sociological perspective within South Africa will be carefully considered. Given the intricate nature of individual business models and the presence of multiple realities, an interpretive paradigm will be followed. Relativism ontological reasoning will guide understanding, complemented by an emic epistemological approach. Inductive reasoning will be employed to derive insights from the data (Denzin & Lincoln, 2000), (Creswell & Creswell, 2018).

Semi-structured interviews were conducted to gather qualitative data, allowing for an in-depth exploration of the challenges and growth trajectories faced by these enterprises. The interviews were recorded, transcribed, and analysed to identify common themes and insights regarding the unique external environmental challenges that micro-QS enterprises encounter. From reviewing historical qualitative research studies, Creswell & Creswell (2018) concluded that the number of participants involved in narrative phenomenological studies range between one and ten. An average number of five participants was selected.

Five micro-QS enterprises, located in various metropolitan regions of South Africa, were consciously selected to participate in interviews aimed at sharing their distinct growth trajectories and lessons learned as micro-QS enterprises. These enterprises, each unique in nature, size, and experience, were given a secure communication channel of choice through which to narrate their developmental journeys.

The researcher took comprehensive measures to ensure the complete anonymity of the participants. Furthermore, all interviewees provided informed consent to participate in the study and agreed to indemnify the researcher against any potential claims. Ethical clearance for the study was obtained from the researcher's academic institution.

Research Results

Qualitative narrated content analysis

The five selected interviewees listed in table 2 anonymous according to the interview schedule, at random (no order of preference) . The summarised data per interviewee is limited to age of their enterprise, number of employees, approximate annual turn-over and their field of speciality.

Table 2: Interviewee data

	Age Of Enterprise	Number of employees	Approx. Annual Turn Over	Speciality
Interviewee 1	8 years	1	Less than R3 million	Industrial
Interviewee 2	6 years	2	Less than R3 million	Golf Estates
Interviewee 3	7 years	6	Between R3 and R6 million	Commercial, and Residential
Interviewee 4	12 years	1	Less than R3 million	Commercial, and Industrial
Interviewee 5	4 years	2	Less than R3 million	Commercial, and Residential

The following interview question was posed to all five interviewees.

- *“Reflecting on your growth journey as a micro-QS enterprise and your future aspirations, could you describe the distinct phases of growth your business has experienced, from its startup phase to becoming a mature micro enterprise?”*

A prompting question, *“What are your future aspirations?”* was asked to interviewees 2, 3, and 4.

Table 3: Interviewee responses

Interviewee	Response
Interviewee 1	"I can't clearly define growth phases in my company. There are times when I'm so busy that I've considered forming a partnership. During these periods, I rely on a freelance QS with whom I have a good working relationship. However, there are also quieter times when I have to travel 200 km for a single project just to cover taxes, and the professional fees barely cover my expenses. My experience has fluctuated, and while I've grown in age and experience, the future remains uncertain with various possible scenarios."
Interviewee 2	"Six years ago, my partner and I decided to start our own company after working for the same QS firm in the Southern Cape. We had both settled with our families and realised that our salaries weren't enough to cover our expenses. Over the years, we've built good relationships in the area and enjoy the Southern Cape lifestyle, including golf on weekends. We were fortunate to secure contracts with two golf estates for QS services. My partner is also involved in local politics, which has its pros and cons." Future aspirations: "We're now settled with our children in the community and schools. We're in a good place and don't want drastic changes. We're open to work, but if it gets too busy, we'd prefer to hire junior QSs to help. We both value quality of life over wealth."
Interviewee 3	"My brother and I started a townhouse development business while we were in university. After our father passed away during my third year, we used the money he left us to build townhouses, with help from our uncle who managed the finances. My girlfriend at the time (now my wife) came from a QS family, and her father employed us while we were studying. After I became a registered QS, my brother and I started our own QS practice alongside our townhouse developments, and we've been doing this ever since." Future aspirations: "We've reached a point where many people depend on our business's growth—not just our employees, but also specialists, suppliers, and contractors. It can be stressful, but we feel a responsibility to continue growing. Fortunately, the South African economy looks promising after the elections, although I hope the conflicts in Ukraine and Gaza don't escalate."
Interviewee 4	"I studied Quantity Surveying and worked for a construction company while studying. After four years, I decided to start my own PrQS practice but had to work for three more years under a registered QS before qualifying. I couldn't wait to finish and, once registered, I resigned and started my own practice. I had good relationships with clients from my previous job, which helped secure early work for my practice. However, due to the political and economic situation in the country, many anticipated projects didn't materialise, and then COVID struck. Fortunately, I have other businesses, which helps, and I don't have dependents, so I can cut expenses if necessary." Future aspirations: "I'm considering leaving the QS profession. I haven't experienced the growth I hoped for, and quantity surveying no longer excites me. My interests have shifted towards food production."
Interviewee 5	"We're very excited about the future. I started with three cold storage projects during COVID, and now I have eight. They're not large projects, but I realised I couldn't manage them alone due to travel and family commitments. So, four months ago, I invited an old university friend to join the business. He brought valuable experience in residential projects and was happy to come on board. Diversification makes business sense, and having a partner means we can cover for each other in emergencies. It's like reuniting with an old friend. Everything is falling into place after the elections, and business looks promising. We've found the perfect old building for our offices and are looking forward to moving in once the renovations are done."

The five interviews reveal several common themes that highlight the experiences and challenges faced by micro quantity surveying (QS) enterprises. These themes include the fluctuation of business growth, the importance of partnerships and networks, the influence of personal and professional life balance,

the impact of external factors such as politics and the economy, and the evolving aspirations of QS professionals.

Fluctuating business growth

Several interviewees expressed the unpredictable nature of business growth in the micro-QS sector. For example, Interviewee 1 discussed the erratic nature of their workload, oscillating between busy periods that necessitated freelance help and quieter times where even covering expenses was challenging. Interviewee 4 also highlighted the unpredictable business environment, with anticipated projects often failing to materialise due to political and economic instability. These experiences underline the challenge of maintaining consistent growth and the inherent instability faced by micro-QS enterprises.

Growth stages

The interviews provide insight into the various growth stages of micro quantity surveying (QS) enterprises, illustrating the different phases these businesses undergo from inception to maturity. The growth stages observed can be broadly categorised into four phases: startup, initial growth, consolidated growth, and maturity. Each stage is marked by unique challenges, strategies, and developments, reflecting the diverse experiences of the interviewees.

Startup stage

The startup stage is characterised by the establishment of the business, where the focus is on setting up operations, securing initial clients, and navigating the early challenges of running a micro-QS enterprise (Churchill & Lewis, n.d.), (Wiklund et al., 2009b).

Interviewee 3 and Interviewee 4 illustrate this phase clearly. Interviewee 3, who started a townhouse development business during university with their brother, represents the early entrepreneurial spirit where initial capital from an inheritance was used to launch the business. Interviewee 4 similarly describes starting their own QS practice after working for a construction company and completing the required professional qualifications. The emphasis during this stage is on leveraging existing relationships and securing early projects to establish the business.

Initial growth stage

The initial growth stage is marked by an increase in workload, the expansion of client base, and the potential need for additional resources or partnerships to manage the growing demands (Wiklund et al., 2009b).

Interviewee 1 describes a fluctuating experience where the business has periods of intense activity, leading to considerations of forming a partnership to manage the workload. During these busy times, the interviewee utilises a freelance QS to cope with the demand. This stage is also evident in Interviewee 2's narrative, where the interviewees decided to leave their previous employer and start their own firm, driven by the need to secure better financial stability and take advantage of local opportunities like contracts with golf estates. The focus in this stage is on managing growth sustainably and adapting to increased responsibilities.

Consolidated growths stage

The consolidated growth stage involves stabilising the business, often through partnerships or the employment of additional staff to ensure the quality of service and maintain manageable workloads. The enterprise begins to focus on long-term sustainability rather than just survival or immediate growth (Wiklund et al., 2009b).

Interviewee 5 provides a clear example of this stage. After initially starting with a few projects, the interviewee expanded to manage more projects but recognised the limitations of doing so alone. This led to the strategic decision to bring in a former university friend to help manage the business, allowing for better management of both professional and personal commitments. The consolidation stage is about securing a stable position in the market and ensuring that the business can operate efficiently without overextending its resources.

Maturity stage

The maturity stage is characterised by a stable, well-established business with a consistent client base, a clear organisational structure, and a focus on maintaining quality and fulfilling long-term strategic goals (Wiklund et al., 2009b).

Interviewee 3 appears to be at or approaching this stage, where the business has grown to a point where there is a responsibility not just to the business owners but also to employees, contractors, and other stakeholders who rely on the business's continued success. The focus shifts from rapid growth to ensuring the business's ongoing sustainability and addressing external factors like economic conditions that could impact the enterprise.

Reflection on growth stages

Across these interviews, it is evident that the growth stages are not linear and can vary significantly based on external factors, personal decisions, and the broader economic environment. For instance, Interviewee 4 discusses the potential stagnation or regression of their business, considering a shift away from the QS profession due to unmet growth expectations and a lack of fulfilment, demonstrating that growth is not guaranteed and can be disrupted or redirected at any stage.

Key takeaways from these growth stages include the importance of adaptability, strategic partnerships, and the need to balance personal and professional life as the business evolves, also highlighted by Churchill (Churchill & Lewis, 1983), Wiklund (Wiklund et al., 2009c), and Kurniati (Kurniati Bachtiar et al., 2019).

Importance of partnerships and networks

The significance of partnerships and professional networks is a recurring theme. Interviewees 1, 2, 3, and 5 all emphasised the value of collaboration. Interviewee 1 discussed working with a freelance QS during busy periods, while Interviewee 2 spoke about starting a company with a partner to ensure financial stability. Interviewee 3 detailed the collaborative nature of their business with their brother, and Interviewee 5 discussed bringing in a university friend to help manage an expanding portfolio. These partnerships not only provide support during growth but also allow these micro-QS enterprises to diversify and manage workload effectively. This finding is supported by various studies (Dobbs & Hamilton, 2007), (Obeng, 2019).

Balancing personal and professional life

The interviews also highlight the need to balance personal and professional life, with several participants prioritising lifestyle and family considerations over aggressive business growth. Interviewee 2, for instance, expressed a preference for maintaining a quality lifestyle over seeking wealth, a sentiment echoed by Interviewee 5 who decided to bring in a partner to balance business commitments with family life. This emphasis on balance suggests that for many in the micro-QS sector, professional success is intertwined with personal fulfilment and quality of life which was also confirmed by Perren (Perren, n.d.).

Impact of external factors

External factors such as political, economic, and global events also play a crucial role in shaping the experiences of these micro-QS enterprises. Interviewees 3 and 4 both highlighted the influence of broader economic conditions on their business operations. Interviewee 3 noted the pressure to grow the business to support employees and contractors, while Interviewee 4 considered leaving the profession due to unmet growth expectations and shifting interests, influenced by the economic landscape. Additionally, Interviewee 5 mentioned the positive outlook following the elections, reflecting how external events can significantly affect business confidence and planning (Aghimien et al., 2018), (Murphy & Seriki, 2021), (Çidik, 2023), .

Evolving aspirations

The evolving aspirations of the interviewees reflect a dynamic and sometimes uncertain professional journey. Interviewee 1 expressed uncertainty about the future, while Interviewee 4 considered shifting careers due to a lack of excitement in quantity surveying. On the other hand, Interviewee 5 expressed optimism about future growth and expansion. These varying aspirations highlight the diverse paths micro-QS professionals may take, influenced by both personal interests and external circumstances (Kerr et al., 2018).

Summary

From the interviews it was found that each interviewee's experience reflects a different aspect of their growth stages, providing a comprehensive view of the lifecycle of micro-QS enterprises in South Africa.

Figure 4 summarises the matters raised by the interviewees affecting the growth of micro-QS enterprises.

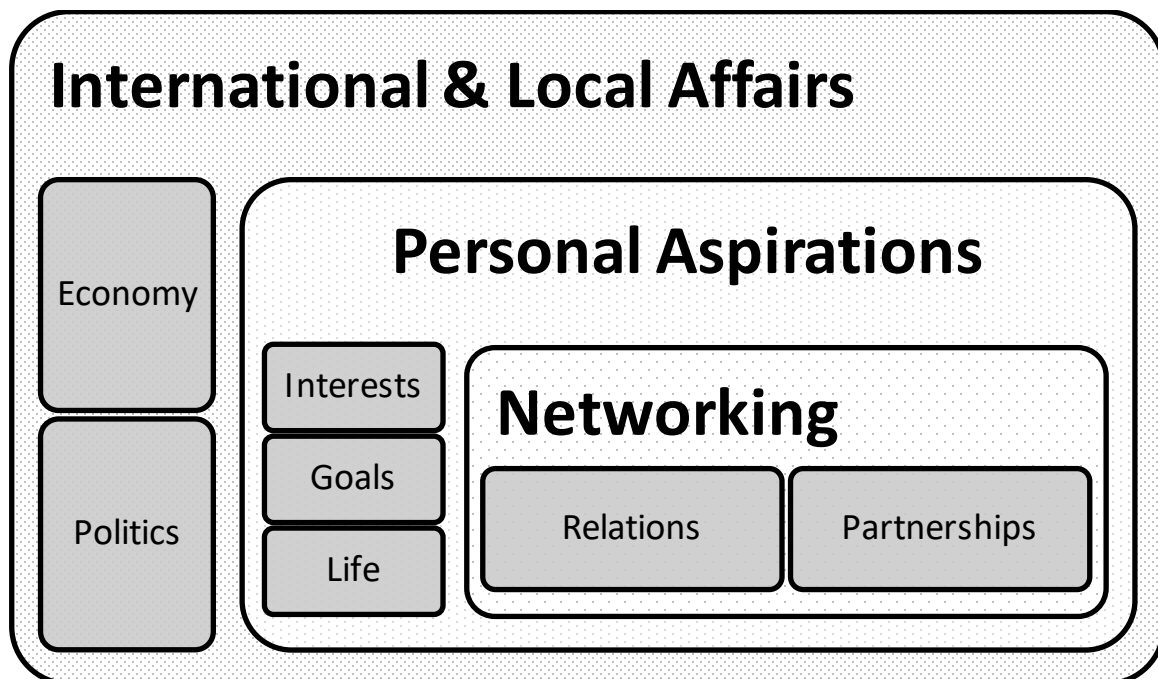


Figure 4: Matters affecting growth of micro-QS enterprises

These insights can help to understand the challenges and opportunities at each stage, guiding future micro-QS enterprises through their growth trajectories.

Conclusion

These common themes suggest that micro-QS enterprises in South Africa operate in a highly volatile environment, requiring adaptability, strong professional networks, and a balance between personal and professional goals. The interviews reveal that while growth is desired, it is often tempered by the realities of external pressures and the need for a sustainable work-life balance. These insights provide a nuanced understanding of the challenges and aspirations within the micro-QS sector, emphasising the importance of flexibility, collaboration, and the ability to navigate both personal and external challenges in pursuing business success.

The study's objective of employing a social constructivist approach to engage with micro-quantity surveying enterprises in South Africa—aimed at understanding the unique circumstances surrounding their businesses and growth—was successfully achieved. However, the broader aim of the research, which is to establish a Growth Stage Model (GSM) specifically tailored for micro-QS startups, providing

a framework to analyse their development from inception to maturity while accounting for the distinct parameters associated with each phase, requires further investigation.

Recommendations

The primary advantage of maturity models lies in their ability to provide a clear and structured progression path for organisations. These models offer a systematic roadmap that guides enterprises through various stages of growth, enabling them to track progress and align resources and efforts with strategic goals. Maturity models also facilitate benchmarking against predefined measurement guidelines, allowing organisations to identify gaps in their growth process. This benchmarking process highlights areas that require improvement, offering the opportunity to implement corrective measures that enhance effectiveness and drive growth. Research into business growth stage models and maturity frameworks adopts a holistic approach to understanding business lifecycles of micro-QS enterprises. However, a notable gap exists in concentrating solely on specific business sizes and service categories, like micro-QS enterprises. This study is limited to only five interviewees which provide the opportunity for further research to unravel the factors affecting the growth of micro-QS enterprises. This research could provide valuable new information highlighting the current unknown factors influencing growth.

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Navigating the Future of Quantity Surveying in South Africa: The Challenges and Benefits of Integrating Artificial Intelligence into the Quantity Surveying Profession

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Abstract

This study explores the challenges and benefits of integrating AI into the QS profession, thus enabling quantity surveyors to manage cost and project lifecycle better and focus on strategic, value-adding activities, a shift from traditional methods towards modernising the profession. The study presents a literature review and subsequent empirical findings by conducting a quantitative analysis based on primary data from quantity surveyors working in Gauteng via a structured questionnaire design. The questionnaires were circulated to about 130 quantity surveyors in Gauteng, selected through convenience sampling. About 70 of the responses were received, and the findings were analysed. The findings reveal that the benefits of AI integration into the QS Profession include faster data processing, improved client satisfaction, and automation of repetitive tasks. Challenges involve resistance to change, high implementation costs, a skills gap, and a lack of local AI solutions tailored to South Africa. This study's focus on AI integration in the QS Profession in South Africa may have overlooked the broader global trends; however, global trends are drawn upon in the conceptualisation and writing of the paper. The rapid evolution of technology might outpace the study's findings, emphasising the need for ongoing research to update and validate the proposed strategies continuously. The study highlights digital disruption in quantity surveying, providing insights for South African QS practitioners and stakeholders to leverage advanced technologies. It reveals the transformative impact of AI on efficiency, innovation, and growth, offering practical strategies for policymakers to mitigate integration challenges and ensure sustainable integration in the construction industry. The paper enriches the conference theme by revealing how AI can revolutionise the QS Profession in South Africa. It offers a forward-looking perspective essential for the profession's adaptation to digital transformation and technological integration.

Keywords: Artificial Intelligence, Quantity Surveying, Challenges, Benefits, South Africa.

Introduction

The construction industry has undergone substantial transformations due to industrialisation, globalisation, and digitalisation. Naser (2019) informs that the industry is expected to face significant developments, including a shift towards a product-based approach, increased specialisation, enhanced value-chain control and supply chain management, industry consolidation, a stronger focus on customer-centricity, greater investment in technology and human resources, further internationalisation, and a heightened emphasis on sustainability. The industry comprises stakeholders and professionals such as clients, project managers, architects, structural engineers, and quantity surveyors, among others, who ensure a project's complete and successful implementation. Quantity surveying is a crucial construction profession involving cost estimation, budgeting, and financial management. The QS is highly skilled in strategising to maximise the use of project resources, maintaining the highest level of professionalism in relationships with other involved parties (Akinshipe, Ikuabe & Aigbavboa, 2022). An essential role is estimating project costs, which is usually done manually depending on the QS's maturity level and experience. The precision of measurements mainly relies on the quantity surveyor's reasoning ability, which can be improved with digitalisation. Digitalisation is revolutionising the construction industry, and with Artificial Intelligence (AI) playing pivotal roles in transforming traditional practices, the QS Profession would immensely gain from these technologies. AI is poised to enhance accuracy, efficiency, and decision-making in the profession, offering a range of promising prospects. Adesi et al., (2018) predicted that, with the emergence of AI technologies such as the Internet of Things sensory

networks, robotics, and automation among others, the construction firms' processes stand to become one with a competitive advantage over other industries (Adesi, Owusu-Manu & Murphy, 2018).

The QS Profession is gradually adopting technological innovations in work practices, including predictive analytics and automation of routine tasks, which enhance accuracy and efficiency in project and finance management. Quantity Surveyors are amongst the first in the construction industry to embrace technologies such as BIM, Excel, DimensionX, and CostX, among others (Akinshipe, Aigbavboa, Oke & Sekati, 2021). Unlike the Construction industry in South Africa, other countries have embraced the use of emerging AI technologies (Aghimien, Adegbembo, Aghimien & Awodele, 2018; Hawksworth, Berriman & Goel, 2018; Oke, Aghimien, Aigbavboa & Koloko, 2018). The progression of technologies has undoubtedly brought numerous benefits to the quantity surveying profession. However, it also presents challenges for quantity surveyors, as automation is expected to eventually replace many of their traditional roles (Tee & Kamal, 2021; Yi, Abdul-Majid, Aziz & Yang, 2023). The adoption of AI technologies will inevitably cause changes in work patterns and data security issues, which may lead to some resistance and also the high cost involved in its integration (Oke et al., 2018); however, these improvements will develop new markets and increase the productivity and profitability of QS firms and the profession in general (Akinshipe et al., 2022). However, a significant gap identified is that despite QS firms and professionals being aware of the advantages of AI tools, full implementation remains limited in Gauteng. The adoption rate of digital tools for daily tasks has been noted to be relatively low (Akinshipe et al., 2021). The study addresses the gap by exploring the issues that hinder AI integration and the benefits of AI in the QS profession in the SA construction industry.

This study was carried out in the Gauteng Province of South Africa and was structured with a quantitative approach. The study is grounded on the Diffusion of Innovation Theory (Rogers & Adhikarya, 1979). The study explores the benefits and challenges of integration of AI technologies in the QS Profession. It provides relevant insights through a comprehensive literature review into the significant benefits of integrating Artificial Intelligence (AI) technologies within the QS Profession in the South African construction industry. It further explores the challenges the industry must overcome to implement AI technologies in its day-to-day QS activities. The study concludes with final observations on the future of AI in the QS Profession and provides strategic recommendations for successful integration, along with potential areas for further research.

Literature Review

Overview of Artificial Intelligence in South African quantity surveying practice

Digital technologies in construction can be divided into four primary categories. The first category includes software for engineering and architectural drawings, word processing, and cost estimation. The second category comprises tools for digitally capturing project data. The third category involves repositories and databases for structured information on equipment, building materials, and machinery (Tung, Chia & Yong, 2021). The final category consists of intelligent systems technologies that facilitate the collaboration, communication, integration, and coordination of information, processes, activities, and personnel involved in project delivery (Ibem, Aduwo, Ayo-Vaughan & Tunji-Olay, 2018). Within the South African construction industry, digital technology is used in several aspects of the construction process. Digitalisation has mostly been adopted by the South African construction industry during the feasibility and design phases of construction (Adeniran & Shakantu, 2023). Abioye *et al.*, (2021) note there are several AI subfields applications used in construction. The advanced QS profession makes use of machine learning algorithms, knowledge-based systems, and optimisation software for improved results in cost estimation.

Artificial Intelligence in quantity surveying profession

Construction jobs rank as the third most vulnerable to automation, following transportation, storage, and manufacturing, over the next decade. This is driven by the growing adoption of technologies like AI and IoT (Hawksworth *et al.*, 2018). Medium-to low-skilled jobs in the construction industry are especially vulnerable to automation, with estimates putting the chance of automation at 38–45% by the mid-2030s (Hawksworth *et al.*, 2018). In the construction industry, established methods are preferred over novel but unproven technologies that provide significant benefits (Babič & Rebolj, 2016). AI is described as a system's ability to correctly interpret external data, learn from it, and use these learnings to achieve

explicit goals through flexible variation (Kaplan & Haenlein, 2019). AI has the potential to augment or replace human tasks through recognition, understanding, learning, and action (Dwivedi, Hughes, Ismagilova, Aarts, Coombs, Crick *et al.*, 2021). Depending on the project phase and specific needs, a QS can function as a consultant QS or a main contractor QS (Mbachu, 2015). QSs are experts in cost management, contract oversight, and procurement in construction. AI offers the potential to enhance their skills and capabilities further (Abioye *et al.*, 2021). AI can support their focus on decision-making, collaboration, and creating sustainable built environments, reinforcing their status as highly skilled professionals in the industry (Akinshipe *et al.*, 2022; Morandini, Fraboni, De Angelis, Puzzo, Giusino *et al.*, 2023; Pollock, 2024). For instance, in the South African construction industry, Building Information Modelling (BIM) software is extensively used due to its benefits for architects, quantity surveyors, and engineers (Kekanaa, Aigbavboa & Thwala, 2015). BIM tools like ArchiCAD and Revit assist planners and designers in producing optimal designs that comply with relevant statutes. (Adebowale & Agumba, 2024) highlights advantages such as improved visualisation, increased productivity from accessible data, and better coordination of documents. The Royal Institution of Chartered Surveyors (RICS) views BIM acceptance as an prospect for surveyors, though failing to embrace BIM could render traditional QS roles less relevant (Seidu, Young, Adafin & Adamu, 2020). The integration of AI and its advanced techniques with BIM can enhance predictions, reduce cost overruns, and minimise waste, optimising design and ensuring compliance, thus promoting efficiency and sustainability in construction (Abioye *et al.*, 2021). Another technology to be leveraged is the Blockchain, which allows for smart contracts and transparency during procurement processes (Mehdi, 2020). However, the construction industry is among the least sectors (Hawksworth *et al.*, 2018) , and the prevalent fear of change often leads to resistance. However, it is gradually moving from traditional methods, especially in the QS profession, with the adoption of BIM, among others, to becoming a more construction-tech industry (Lekan, Aigbavboa, Fayomi & Owolabi, 2020).

Several challenges identified in the literature inhibit the smooth integration of AI technologies into the QS profession. The high cost of owning and utilising AI technologies poses a significant challenge (Hussain, Akram, Ahmed, Usama & Hussain, 2019; Afzal, Yunfei, Nazir & Bhatti, 2021). Again, AI security is vulnerable to cybercriminals even with several advancements over the years (Oke *et al.*, 2018; Khanna & Sharma, 2019). The identified challenges from various research literature are identified as the high cost of owning and utilising AI technologies poses a significant challenge, as these technologies are not completely developed yet and necessitate ongoing investment to remain current with advancements (Hussain *et al.*, 2019; Afzal *et al.*, 2021) The competencies of AI technologies while promising great outputs, could also be dangerous if not properly regulated by institutions and the government. It can cause ethical and legal issues as well as face several cultural barriers to integration (Daly, Hagendorff, Li, Mann, Marda *et al.*, 2019; Le Jeune, Ontong & Moghayedi, 2023; Sawhney, Franco, Tong, Pitman & Reed, 2023). There is a high impact on traditional skills which may impact job availability as new technologies are integrated (Mathis, 2019; Tee & Kamal, 2021). Also, AI integration faces high resistance from industry bodies (Ikuabe, Aghimien, Aigbavboa & Oke, 2020; Lekan *et al.*, 2020) The skills gap poses another major challenge with AI integration into the QS Profession (Abioye *et al.*, 2021; Morandini *et al.*, 2023; Yi *et al.*, 2023). There is also the inability of new technologies to integrate with other systems (Jamal, Mohammad & Hashim, 2019) which may lead to several disruptions in operations (Taher, G., 2021). The construction industry also faces significant collaboration challenges (Oke *et al.*, 2018). There is also the issue of stakeholder buy-in where acceptance of new technologies may face resistance and scepticism (Gamil & Rahman, 2019; Akinshipe *et al.*, 2022; Ramos, 2023). Table 1 provides a summary of the reviewed benefits of integrating AI technologies into QS Profession.

Table 1: Challenges of integrating AI technologies in the QS profession

Challenges of integrating AI Technologies in the QS Profession	Author(s)
Job displacement fears	Mathis, 2019; Tee & Kamal, 2021; Caleb, 2024
Cybersecurity risks	Oke <i>et al.</i> , 2018; Khanna & Sharma, 2019
Skills gap	Abioye <i>et al.</i> , 2022; Morandini <i>et al.</i> , 2023 Yi <i>et al.</i> , 2023;
High implementation costs	Hussain <i>et al.</i> , 2019; Seidu <i>et al.</i> , 2020; Taher, 2021; Afzal <i>et al.</i> , 2021
Lack of local AI solutions tailored to the South African context	Mtuzze & Morige, 2024
Ethical and legal concerns	Daly <i>et al.</i> , 2019; Le Jeune <i>et al.</i> , 2023; Sawhney <i>et al.</i> , 2023.

Data quality and standardisation issues	Wang, Zhang & King, 2016; Gamil & Rahman, 2019; Ben Rabia & Bellabdaoui, 2023; Sawhney et al., 2023
Regulatory and compliance challenges	Sawhney et al., 2023; Seah 2021; Oke et al., 2018
Limited digital infrastructure	Yi et al., 2023; Galera-Zarco & Floros, 2024; Vishwakarma, Singh, Mishra & Venkatesh, 2024.
Difficulty with integration with existing systems	Jamal et al., 2019
Cultural Barriers	Daly et al., 2019; Abioye et al., 2021; Caleb, A., 2024
Operational Disruptions	Khanna & Sharma, 2019; Taher, 2021
Data availability issues	Wang, Zhang & King, 2016; Gamil & Rahman, 2019; Ben Rabia & Bellabdaoui, 2023
Stakeholders' buy-in (Stakeholders' trust and acceptance)	Gamil & Rahman, 2019; Akinshipe et al., 2022; Ramos, 2023
Resistance to Change	Ikuabe et al., 2020; Lekan et al., 2020

Source: Researcher's construct, 2023

AI technologies also have benefits to offer, such as analysis of a variety of construction projects to make accurate cost predictions and also forecast unknown expenses and reduce cost overruns (Seidu *et al.*, 2020; Ashtari, Ansari, Hassannayebi & Jeong, 2022). In comparison to traditional cost estimation, AI technologies improve project cost estimations. Better project scheduling and resource allocation (Jain, Jauhar, & Piyush, 2024). Increased productivity and efficiency (Asuquo, Oladokun & Adelakun, 2020; Morandini *et al.*, 2023). AI can also reduce the risk of human errors by automating contract management tasks, ensuring faster and more accurate processes (Reddy, 2017; Mehdi, 2020; Akinradewo, Aigbavboa, Oke & Edwards, 2023; Adekunle, Aigbavboa, Ejohwomu, Adekunle & Thwala, 2024), together with reduced time spent on repetitive tasks (Regona, Yigitcanlar, Xia & Li, 2022). Additionally, AI technologies also foster innovation which brings out the competitive advantage of QS firms (Vermaak & Crafford, 2023; Adekunle *et al.*, 2024), it also ensures accurate evidence-based decision-making and enhanced cost control and progress monitoring (Chowdhury, Adafin & Wilkinson, 2019; Elrefaey, Ahmed, Ahmad & El-Sayegh, 2022; Sawhney *et al.*, 2023). With the integration of AI technologies, new jobs will be created which may include researchers, trainers and engineers in AI (Uhm, Lee & Jeon, 2017; Morandini *et al.*, 2023). Overall, the identified benefits lead to client satisfaction as work is more accurate and efficiently delivered (Seidu *et al.*, 2020; Akinshipe *et al.*, 2021). Table 2 provides a summary of the reviewed benefits of integrating AI technologies into the QS profession

Table 2: Benefits of integrating AI technologies in the QS profession

Benefits of integrating AI Technologies in the QS Profession	Author(s)
Improved accuracy in cost estimation	Yi et al., 2023
Enhanced project planning and scheduling	Seidu <i>et al.</i> , 2020; Jain, Jauhar, & Piyush, 2024
Faster data processing and analysis	Seidu <i>et al.</i> , 2020; Ashtari, Ansari, Hassannayebi & Jeong, 2022; Regona, Yigitcanlar, Xia & Li, 2022; Sawhney et al., 2023
Job creation (New AI job roles)	Sawhney et al., 2016; Uhm, Lee & Jeon, 2017; Morandini et al., 2023
Automated document management	Reddy, 2017; Yi et al., 2023; Akinradewo, Aigbavboa, Oke & Edwards, 2023
Competitive Advantage	Adesi et al., 2018
Predictive analytics for risk assessment	Seidu et al., 2020; Mehdi, 2020; Ashtari et al., 2022
Increased productivity and efficiency	Asuquo et al., 2020; Anderselite, 2020; Morandini et al., 2023
Better resource allocation	Waltersmann, Kiemel, Stuhlsatz, Sauer & Miehe, 2021; Jain, Jauhar, & Piyush, 2024
Automation of Repetitive Tasks	Akinshipe et al., 2021; Abioye <i>et al.</i> , 2021; Akinshipe <i>et al.</i> , 2022; Regona et al., 2022
Enhanced skills	Kim & Park, 2018; Adekunle et al., 2021; Yi et al., 2023
Enhanced ability to handle complex project data	Adekunle et al., 2021; Akinshipe et al., 2021
Enhanced project stakeholders' collaborations	Hogg & Higgs, 2013; Yi et al., 2023
Real-time project monitoring and reporting	Chowdhary, 2019; Yi et al., 2023
Improved sustainability through better resource management	Ramakrishnan, Seshadri, Liu, Zhang, Yu & Gou, 2023; Akinshipe et al., 2022; Morandini, et al., 2023; Pollock, 2024;
Innovation and Growth	Adekunle et al., 2021; Vermaak & Crafford, 2023
Improved client satisfaction	Daqar & Smoudy, 2019; Seidu et al., 2020

Source: Researcher's construct, 2024

Although AI is a catchy and trending topic in construction research, there needs to be more literature on the low level of integration in the sector, specifically the Quantity surveying practice. Aghimien *et al.*, (2018) and Akinshipe *et al.*, (2021) affirms the need for the QS Profession to adopt AI technologies as implementation into daily activities is relatively low compared to international counterparts. In bridging this knowledge gap, this paper studies the challenges of integrating AI and the potential benefits offered for the QS Profession in the South African construction industry.

Research Methodology

Research paradigm

A quantitative research approach was selected to investigate the various challenges and benefits of AI integration into the QS Profession in the South African construction industry. This approach is grounded in the positivist philosophical perspective. Positivism asserts that if something cannot be measured or quantified, it cannot be known with certainty (Park, Konge & Artino, 2020).

Population and sample

The study was conducted in Gauteng province, South Africa. The province was chosen due to the researcher's proximity and the relevance of the research problem in this location. The targeted respondents were quantity surveyors in the Gauteng province, South Africa. The respondents were chosen using non-probability sampling with convenient sampling. A convenience sampling technique was adopted due to time constraints and ease of access via an online survey. Convenience sampling involves selecting respondents who are easily accessible to the researcher, without following any specific pattern or method in the selection process (Golzar, Noor & Tajik, 2022). Quantity Surveyors were chosen for the sample because the study seeks to identify the challenges of AI technology integration in the QS Profession as well as the potential benefits of its integration. The study's respondents are professionals who are fully aware of digital technologies and how it is transforming the construction industry and could provide valuable information about research objectives.

Data collection method

The quantitative data for the study was gathered through a survey questionnaire. The questionnaire, developed to rate the significance of identified challenges and benefits from reviewed literature with a five-point Likert scale, was employed as the data collection tool. Questionnaire surveys are structured methods for gathering data from a sample, known for their simplicity and ability to reach a wide audience (Taherdoost, 2021). In two sections the questionnaire was designed; the first section of the questionnaire was to gather data on the background (i.e. gender, level of education, place of work, and work experience); the second section focused on exploring the respondents' perception of the identified challenges and benefits of AI integration into the QS Profession.

Data analysis

The data collected underwent a comprehensive analysis using Statistical Package for Social Sciences (SPSS) v29, employing statistical methods such as mean item score, and standard deviation. To rank respondents' knowledge of the benefits and challenges in the QS Profession within the South African construction industry the Kruskal-Wallis test was employed to test the significant differences in views among the various professionals with varied working experience participating in the study (Pallan, 2011). The responses were then ranked with the Kruskal-Wallis p-values. A normality test was also performed since the data response was less than 100. These analytical tools were consistent with the approach employed by Otasowie, Aigbavboa, Oke & Adekunle, (2024). The reliability of the questionnaire was evaluated using Cronbach's alpha test. Cronbach's alpha produces a value between 0 and 1, with higher values reflecting a higher level of internal consistency (Williams, Onsmann & Brown, 2010). The Cronbach's alpha test for the study yielded a score of 0.855. The results of the analysis are presented in the next section.

Research Results

The questionnaires were circulated to about 130 QS Professionals selected through convenience sampling. The questionnaires were sent via email through the Google Forms link, with 70 responses received for analysis. This corresponds to a 54% response rate from the total questionnaire disseminated. A 54% response rate is believed adequate for the study as informed by Duncan (2008) who stated that a response rate of 20% to 30% and 50% respectively is considered suitable for social research online surveys in a population of professionals. The results of the data analyses using the SPSS version 29 are presented.

Background information of respondents

The survey results reveal 58.6% male and 40% female respondents, also 1.4% preferred not to say. Most respondents have Bachelor's degree (34.3%), Bachelor's Honours degree (30.0%), Master's degree (21.4%), PhD degree (11.4%), with the least academic qualification being Diploma with just (2.9%). 48.6% of respondents work in the private sector, 35.7% in the public sector, and 15.7% in other non-governmental organisations. The highest year of experience falls between the 1 to 5 years and the less than 12 months range with 47.1% and 21.4%, respectively. On average, the respondents' years of experience are 11.6 years. With these average years of experience of the respondents and their academic qualifications, it is believed that they were well-equipped to comprehend and respond reasonably to the study's aim.

Results of challenges and benefits of AI integration in QS profession in South Africa

The Shapiro-Wilk test was conducted to determine the nature of the data gathered via a normality test. This was done to determine whether the data collected was non-parametric or parametric. Since the sample size is less than 100 there was a need for the normality test as suggested in Ghasemi & Zahediasl (2012). The results in Table 3 indicate that the significance value for all assessed challenges is below the 0.05 threshold for normality. Therefore, the data cannot be analysed using normal parametric statistical techniques, as it is non-parametric.

Table 3: Normality test for challenges and benefits of AI integration in QS in the SA construction industry

Challenges	Statistic	Df	Sig.
Job displacement fears	0.862	70	0.001
Cybersecurity risks	0.830	70	0.001
Skills gap	0.807	70	0.001
High implementation costs	0.793	70	0.001
Lack of local AI solutions tailored to the South African context	0.819	70	0.001
Ethical and legal concerns	0.883	70	0.001
Data quality and standardisation issues	0.868	70	0.001
Regulatory and compliance challenges	0.865	70	0.001
Limited digital infrastructure	0.781	70	0.001
Difficulty with integration with existing systems	0.870	70	0.001
Cultural Barriers	0.838	70	0.001
Operational Disruptions	0.858	70	0.001
Data Availability issues	0.855	70	0.001
Stakeholders' buy-in (Stakeholders' trust and acceptance)	0.813	70	0.001
Resistance to Change	0.761	70	0.001
Benefits	Statistic	Df	Sig.
Improved accuracy in cost estimation	0.788	70	0.001
Enhanced project planning and scheduling	0.787	70	0.001
Faster data processing and analysis	0.730	70	0.001
Job creation (New AI job roles)	0.837	70	0.001
Automated document management	0.797	70	0.001
Competitive Advantage	0.788	70	0.001
Predictive analytics for risk assessment	0.761	70	0.001
Increased productivity and efficiency	0.777	70	0.001
Better resource allocation	0.787	70	0.001
Automation of Repetitive Tasks	0.768	70	0.001
Enhanced skills	0.829	70	0.001
Enhanced ability to handle complex project data	0.764	70	0.001
Enhanced project stakeholders' collaborations	0.798	70	0.001
Real-time project monitoring and reporting	0.773	70	0.001
Improved sustainability through better resource management	0.792	70	0.001

Innovation and Growth	0.765	70	0.001
Improved client satisfaction	0.746	70	0.001

Df=Degree of freedom

As the continuous variables were not normally distributed as per the Shapiro-Wilk test, the difference in continuous variables by years of experience was assessed using the Kruskal-Wallis's test (an alternative to the one-way ANOVA). The aim was to ascertain the significant difference attached to each challenge and the benefit. The results comprise the Kruskal-Wallis test, which offers valuable data on the statistical significance of each challenge and benefit variable against the 'Years of experience'. The means and standard deviations presented provide an understanding of the variability of responses. The findings, however, indicated that there was no statistically significant difference among respondents' responses for both the challenges and benefits of integrating AI into the QS Profession in the South African Construction industry. Results in Table 4 show the challenges of AI integration into the QS Profession in the South African construction industry as rated by the respondents. It also presents the Kruskal-Wallis H value and the corresponding significant p-value for each challenge assessed through the Kruskal-Wallis Test. The table indicates that all the evaluated challenges significantly impact the integration of AI in the QS Profession within the South African construction industry, with a mean value well above the average of 3.5 (Aghimien et al., 2018). The results show that the main challenges are resistance to change, high implementation cost, skills gap, limited digital infrastructure and lack of local AI solutions tailored to the South African context with mean values of 4.03, 4.03, 4.00, 3.96 and 3.86.

The results in table 5 depicts of the Kruskal-Wallis test and a summary of the mean item scores and standard deviations as well as the rankings using the mean values.

Table 4: Kruskal-Wallis H test for challenges of integrating AI in the QS profession in South Africa

Challenges	K-W value	Sig. (p-value)	Mean	SD	R
Resistance to Change	3.294	0.655	4.03	1.154	1
High implementation costs	2.867	0.721	4.03	1.156	2
Skills gap	4.067	0.540	4.00	1.007	3
Limited digital infrastructure	1.651	0.895	3.96	1.083	4
Lack of local AI solutions tailored to the South African context	1.165	0.948	3.86	1.133	5
Data quality and standardisation issues	5.715	0.335	3.77	1.038	6
Stakeholders' buy-in (Stakeholders' trust and acceptance)	4.251	0.514	3.76	1.096	7
Regulatory and compliance challenges	2.196	0.821	3.71	1.051	8
Data Availability issues	3.845	0.572	3.70	1.147	9
Job displacement fears	1.696	0.889	3.69	1.246	10
Operational Disruptions	3.022	0.697	3.67	1.086	11
Cultural Barriers	5.954	0.311	3.63	1.066	12
Cybersecurity risks	3.536	0.618	3.53	1.073	13
Ethical and legal concerns	2.141	0.829	3.53	1.151	14
Difficulty with integration with existing systems	2.087	0.837	3.49	1.271	15

SD=Standard Deviation

Table 5 shows the results of the Kruskal-Wallis test and a summary of the mean item scores and standard deviations as well as the rankings using the mean values.

Table 5: Kruskal-Wallis test for the benefits of integrating AI in the QS profession in South Africa

Benefits	K-W value	Sig. (p-value)	Mean	SD	R
Faster data processing and analysis	6.241	0.283	4.43	0.650	1
Improved client satisfaction	3.632	0.604	4.41	0.648	2
Automation of Repetitive Tasks	4.470	0.484	4.36	0.723	3
Innovation and Growth	1.517	0.911	4.34	0.657	4
Enhanced ability to handle complex project data	0.681	0.984	4.34	0.679	5
Increased productivity and efficiency	4.585	0.469	4.33	0.717	6
Better resource allocation	1.577	0.904	4.30	0.749	7
Predictive analytics for risk assessment	4.305	0.506	4.30	0.840	8
Enhanced project planning and scheduling	4.229	0.517	4.27	0.700	9
Real-time project monitoring and reporting	9.204	0.101	4.27	0.815	10

Improved sustainability through better resource management	5.857	0.320	4.26	0.774	11
Improved accuracy in cost estimation	3.026	0.696	4.24	0.690	12
Enhanced project stakeholders' collaborations	5.005	0.415	4.24	0.788	13
Automated document management	8.740	0.120	4.24	0.824	14
Competitive Advantage	5.064	0.408	4.21	0.883	15
Enhanced skills	7.720	0.172	4.11	0.808	16
Job creation (New AI job roles)	2.643	0.755	4.03	0.963	17

SD=Standard Deviation

A quick review of Table 5 reveals that all the assessed benefits have a mean value exceeding the average of 4.0. Thus, implies that all the perceived benefits according to the literature are actual benefits of AI integration in the QS Profession in the SA construction industry for the identified construction processes. Results show the top four benefits of AI technologies are faster data processing, improved customer satisfaction, automation of repetitive tasks, innovation and growth and enhanced ability to handle complex data with a mean score of 4.41, 4.43, 4.36, 4.34 and 4.34. The analysis aims to contribute additional knowledge to existing literature on the perceived challenges of adopting new technology in the construction industry specifically the QS Profession and provide an understanding of the benefits associated with accepting and integrating these new AI technologies within the South African context.

Discussions

The construction industry is often slow to adopt new practices, leading to persistent challenges such as waste and cost overruns, which have negatively impacted the industry and hindered the adoption of technology (Olatunji, Sher & Gu, 2010). By 2030, it is projected that 14% of the global workforce might need to transition to different jobs due to advancements in AI technology (Morandini *et al.*, 2023). The result of the survey is further discussed in this section.

Challenges of Artificial Intelligence integration in QS in the SA construction industry

A major challenge of AI integration into the QS Profession in the South African construction industry from the results is resistance to change. This can be attributed to the ease of use of traditional methods and scepticism about the benefits of AI. This finding corroborates with Lekan *et al.*, (2020) that changes in traditional methods can cause some resistance and this can be due to fear of job displacement as new technologies are introduced (Mathis, 2019; Caleb, 2024). AI replacing human tasks is one of the significant challenges identified by participants. The costs involved in initial adoption can deter firms, particularly smaller ones, from investing in these advancements. These costs include the purchase of AI systems and the expenses related to training, system integration, and ongoing maintenance (Hussain *et al.*, 2019; Afzal *et al.*, 2021). Another challenge that is identified as a hurdle is the existing skills gap. Due to the traditional means of performing QS activities, QS Professionals may lack the technical knowledge required to use AI tools as identified in the industry effectively (Abioye *et al.*, 2021; Morandini *et al.*, 2023). Further discussing the challenges, it is clear that the absence of AI solutions tailored to the South African context stems from the lack of a regulatory framework for AI integration in the construction sector (Mtuze & Morige, 2024). The study identifies limited digital infrastructure as significant. Particularly in developing nations such as South Africa, this can significantly impede the integration of AI in quantity surveying. The limited availability of hardware and software to support AI technologies can be traced to financial constraints, this challenge makes it difficult for firms to leverage AI capabilities fully (Galera-Zarco & Floros, 2024; Vishwakarma *et al.*, 2024). Data quality and standardisation are crucial for effective AI integration. Poor data quality and a lack of standardised formats can lead to inaccurate predictions and insights, reducing the reliability and usefulness of AI in QS tasks (Wang, Zhang & King, 2016; Gamil & Rahman, 2019; Ben Rabia & Bellabdaoui, 2023). Gaining stakeholder acceptance is vital for the successful integration of AI. Clients, contractors, and other stakeholders may be wary of AI's role in decision-making processes, especially without fully comprehending its benefits (Gamil & Rahman, 2019; Ramos, 2023). Cultural barriers as a challenge can be related to the deeply ingrained practices and preferences for traditional methods. Additionally, Ethical and legal concerns related to data privacy and cybersecurity risks of AI systems are critical issues which have been identified by several studies and reiterated by this study (Daly *et al.*, 2019; Abioye *et al.*, 2021; Caleb, 2024). The integration of AI into existing systems and workflows can be a complex process, especially if legal systems are outdated or incompatible with new technologies

(Omoga, 2023). Regulatory inconsistencies and compliance are another important challenging factor. AI applications in QS must adhere to industry regulations and standards. Navigating the regulatory landscape requires a thorough understanding of the legal requirements specific to the AI and QS profession in the South African context, and this is quite a hurdle (Oke *et al.*, 2018). The challenges of AI integration identified by respondents can be said to be systemic, and from the above discussion, the interconnectedness of the challenges becomes evident.

Benefits of integrating Artificial Intelligence in QS in the SA construction industry

From the results, the primary benefit of AI integration in the QS Profession in South Africa by participants is the faster processing and analysis of data, which enables QS Professionals to handle large volumes of data more efficiently. This in turn, could lead to quicker and more informed decision-making that reduces cost overruns (Seidu *et al.*, 2020; Ashtari *et al.*, 2022; Regona *et al.*, 2022). Also, with the quick output of analysis and decision making there is improved client satisfaction which is important as projects can be delivered more swiftly and with greater precision (Daqar & Smoudy, 2019). Automation of repetitive tasks is also identified as a significant benefit, which corroborates with previous study findings (Abioye *et al.*, 2021; Akinshipe *et al.*, 2022). For repetitive tasks such as data entry and routine calculations, AI allows for automation, freeing up QS Professionals to focus on more strategic activities, and fostering innovation and growth within the industry. Furthermore, AI can contribute to improved sustainability through better resource management by optimising the use of materials and minimising waste, which is increasingly important in today's environmentally-conscious construction industry (Ramakrishnan, Seshadri, Liu, Zhang, Yu & Gou, 2023; Pollock, 2024). Another critical benefit is the improved accuracy of cost estimation provided by AI's advanced algorithms (Tariq, Matthews & Lockley, 2023). This can reduce the likelihood of errors and cost overruns, thereby giving firms a competitive advantage. AI also facilitates real-time project monitoring, allowing QS Professionals to track progress and adjust as needed, ensuring projects stay on schedule and within budget. AI can reduce the risk of human errors by automating contract document management tasks (Mehdi, 2020; Akinradewo *et al.*, 2023). With the integration of AI in the QS Profession, AI jobs are created as the results reveal. New forms of AI jobs will be created, such as construction trainers and engineers, AI researchers, and QS Professionals must be trained to fit in (Uhm *et al.*, 2017; Morandini *et al.*, 2023). Other identified significant benefits of AI integration into the QS Profession include enhanced project planning and scheduling, predictive analytics for risk management (Seidu *et al.*, 2020), and stakeholders' collaborations (Akinshipe *et al.*, 2021; Pollock, 2024). Finally, the integration of AI enhances the skills of QS Professionals by allowing them to leverage advanced tools and technologies, thus staying ahead in a rapidly evolving industry (Akinshipe *et al.*, 2021). These identified benefits highlight the transformative capability of AI in Quantity Surveying, positioning it as a key driver of productivity and efficiency, innovation, and competitive success in the South African construction sector.

The results generally suggest that quantity surveyors in South Africa agree with the integration of AI technologies within the quantity surveying profession and affirm its potential benefits in the QS Profession in the South African construction industry.

Conclusions

The study investigated the challenges and benefits of AI integration in the QS Profession in South Africa. Through a literature review and a survey, it identified resistance to change as the main challenge, as well as high implementation costs, limited digital infrastructure, and job displacement fears. Faster data processing and analysis emerged as the top benefit, improving decision-making, client satisfaction, and profitability, while other advantages include enhanced skills, job creation, and better resource management. The study highlights the need for strategies to overcome challenges for smooth AI integration, offering valuable insights for QS Professionals and stakeholders. Additionally, it contributes to technology adoption theories such as 'Diffusion of Innovation theory' and emphasises the importance of careful planning, digital leadership, and addressing ethical concerns to realise AI's potential in the QS Profession fully. The study also delivers a more nuanced understanding of how these identified factors influence successful integration. This could lead to more context-specific models or frameworks or adaptations of these theories to better explain AI technology integration in construction and other similar industries.

Limitations and Further Study

This study on AI integration in the QS profession in South Africa acknowledges global trends but emphasises the need for ongoing research to keep strategies relevant amid rapid technological advancements, which highlights its main limitation. Future research could investigate how AI affects ethical decision-making in the QS profession, addressing concerns like algorithmic biases, transparency, and accountability to ensure fair outcomes in construction projects.

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Optimising Dispute Resolution Efficiency and Affordability in South Africa's Construction Sector: a Quantity Surveyor's Perspective

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Abstract

The primary objective of this paper is to interrogate the efficiency and affordability of dispute resolution methods in the context of the South African construction industry. A positivist philosophical view was employed through an online questionnaire survey distributed amongst professional quantity surveyors to investigate the cost-effectiveness of established dispute resolution methods. Descriptive and inferential statistics were utilised. Quantity surveying professionals' favour and find arbitration the most efficient approach for resolving disputes. The results also suggest that dispute review boards are the most economical method for dispute resolution. Therefore, the original hypothesis, which suggested mediation as the most cost-effective method, was not supported. The study's exclusive emphasis on registered professional quantity surveyors may restrict the applicability of the results to the wider construction sector. It does not encompass the viewpoints of other key stakeholders, such as contractors, architects, or legal experts. The research offers valuable guidance to quantity surveying professionals. It provides insights as it indicates the most cost-efficient dispute resolution method, aiding industry practitioners in making informed choices on managing and resolving construction disputes more efficiently and cost-effectively. This paper offers insights into the most efficient and affordable dispute resolution methods based on the viewpoint of quantity surveying professionals for implementation in potential disputes.

Keywords: Effectiveness, Cost-Effectiveness, Quantity Surveyors, Construction, Dispute Resolution.

Introduction

In the dynamic and rapidly evolving South African construction industry, effective dispute resolution is a crucial element for maintaining the sector's credibility and ensuring the seamless progression of projects. Construction projects, due to their inherent complexity and the involvement of multiple stakeholders such as contractors, employers, and suppliers, are particularly prone to disputes. These disputes, if not handled effectively, carry substantial financial repercussions that extend beyond immediate costs. They can disrupt project timelines, damage corporate reputations, and undermine the confidence of key stakeholders. Therefore, finding methods that are both effective and affordable for resolving disputes is vital to sustaining the health of construction operations.

The world of effective dispute resolution methods is multifaceted, shaped by various essential considerations. However, the current dispute resolution practices in the industry reveal inefficiencies that need to be addressed. The Royal Institution of Chartered Surveyors (RICS) Report (2013) underscores that the choice of dispute resolution method is dependent on the nature and complexity of the dispute. For disputes that are less complicated, mediation offers an efficient and affordable path to resolution. It allows parties to reach a mutually agreeable solution without incurring the extensive costs of litigation. Mediation fosters communication between disputing parties, providing a platform for dialogue and negotiation. This reduces the need for prolonged legal processes, making it both a time-efficient and cost-effective choice. However, when disputes involve more significant stakes and technical complexities, adjudication may be more appropriate (RICS Report, 2013). Adjudication, while more formal than mediation, still offers faster resolutions than litigation, thus aligning with both effectiveness and affordability in more complex cases (RICS Report, 2013).

The effectiveness of dispute resolution methods also depends on the skills and experience of the professionals managing the process. According to Kumaraswamy and Chan (2016), the expertise of the mediator or adjudicator is a key factor in ensuring effective outcomes. A qualified professional can expedite the process by making prompt decisions with sufficient knowledge to meet the needs of all involved parties. Additionally, the active participation and commitment of the parties involved significantly influence the success of the process (Kumaraswamy & Chan, 2016). Efficiency is compromised when stakeholders are uncooperative or disengaged, leading to protracted disputes and escalating costs. Therefore, the collaboration and commitment of all parties are essential to achieving efficient and cost-effective resolutions (Kumaraswamy & Chan, 2016).

Dikmen et al. (2015) further stress the importance of dispute prevention strategies to enhance both effectiveness and affordability in resolving disputes. Within this realm, both clients and contractors play integral roles. Their role in explicitly defining project specifications, expectations, and requirements within the contract sets a strong groundwork for handling potential disputes (Dikmen et al., 2015). This transparency not only serves as a dispute prevention mechanism but also promotes clarity, which, in turn, positively impacts project outcomes (Dikmen et al., 2015). Furthermore, the importance of effective communication among project team members cannot be overstated when it comes to preventing disputes. Clearly defining expectations and maintaining open lines of communication significantly reduces the chances of disputes, resulting in positive project outcomes (Dikmen et al., 2015).

In the past, litigation stood as the predominant approach to resolving disputes. Nevertheless, due to its complexities and technical aspects, the construction industry has progressively integrated alternative dispute resolution methods (Alozn & Galadari, 2015). While litigation remains one of the most effective and commonly used methods, it also comes with the burdens of being slow, costly, and potentially damaging to business relationships, in agreement with Çevikbaş and Köksal (2018). Echtermach-Jaubert et al., (2021), support the notion that litigation represents the most perilous and costly approach to dispute resolution. They underline the existing dearth of project managers equipped with the knowledge to manage such projects and their limited familiarity with the intricacies of litigation processes. Thomas et al., (2013), highlights that negotiation in construction disputes can occasionally reach an impasse due to the unwillingness of involved parties to make concessions, leading to delays in project completion and increased expenditures. In a similar vein, uncover a limitation of mediation in construction disputes, specifically related to the mediator's inability to enforce agreements reached during the mediation process (Kaming et al., 2013).

For any of the dispute resolution methods to be both effective and affordable, it is essential for project team members to establish unambiguous expectations and cultivate streamlined communication channels. This approach serves a dual purpose, reducing the chances of disputes and ensuring project outcomes align with the intended goals. By promoting transparency and encouraging open communication among stakeholders, a stronger foundation is built for reducing conflicts and increasing the likelihood of positive project outcomes. Essentially, taking proactive measures to establish clear project specifications and cultivate effective communication are vital strategies to prevent disputes and, in the end, attain successful project objectives.

Literature Review

The realm of efficient dispute resolution methods is complex and influenced by numerous crucial factors. As outlined in the RICS Report (2013), the choice of a particular method is contingent upon the distinctive attributes and importance of the specific dispute. Conventional dispute resolution procedures, frequently characterised by adversarial dynamics, can yield situations where one party emerges victorious while the other encounters setbacks throughout project execution (Nigel Preece et al., 2013). This outcome can demotivate the losing party, potentially resulting in a critical situation that hampers project progress (Nigel Preece et al., 2013). When faced with such scenarios, stakeholders have the option to select from negotiation, mediation, arbitration, or litigation as suitable methods for resolving these disputes (Abwunza et al., 2020).

Efficiency and affordability of current dispute resolution methods

Disputes must be identified and addressed promptly and efficiently to avoid project delays and financial strain. In the construction industry, Alshahrani (2017), propose that there are three primary methods for resolving disputes: litigation, arbitration, and alternative dispute resolution. Besaiso et al. (2016) argue

that negotiation and litigation should not be considered as alternative dispute mechanisms. Marale et al. (2017) identify twelve factors that impact the selection of a dispute resolution method, encompassing aspects such as bindingness, cost-effectiveness, confidentiality, control, available remedies, enforceability, fairness, flexibility, privacy, expediency, relationships, and innovation.

The process of litigation can lead to legally binding and enforceable resolutions, instilling a sense of conclusiveness and confidence in dispute resolution (Kaklauskas et al., 2017). When considering financial efficiency, litigation can offer a cost-effective approach to dispute resolution, particularly when compared to alternative methods like arbitration (Chan et al., 2018). This cost-effectiveness arises from the fact that in litigation, the expenses associated with court proceedings are shared between the involved parties, whereas in arbitration, the disputing parties bear the costs of the arbitrator(s) and the entire arbitration process (Chan et al., 2018).

Mediation, a more collaborative approach, is often highlighted as a more affordable and time-efficient option. Carr (2018) emphasises that mediation allows parties to reach mutually satisfactory resolutions without the extended legal procedures and expenses associated with litigation. Mediation encourages communication, which can lead to quicker and more affordable outcomes compared to more formal methods like arbitration or litigation. Arbitration, while generally more expensive than mediation, offers binding awards that help resolve disputes conclusively. Lijesen (2013) points out that arbitration in construction disputes offers a binding resolution that avoids the uncertainties of prolonged court battles, making it an effective option for more complex disputes.

Gross et al. (2014) argue that negotiation emerges as a swifter and more cost-effective approach for settling construction disputes when compared to alternative methods like litigation or arbitration. This efficiency results from negotiation avoiding protracted court proceedings and the accompanying high legal costs.

Dispute Adjudication Boards (DABs) have gained traction as a method that balances efficiency and expertise. Abeynayake and Weddikkara (2018) argue that the strength of DABs lies in their ability to provide quick and cost-effective resolutions. However, their implementation at the project's outset can lead to additional costs, particularly for smaller projects. DABs provide ongoing oversight, helping to prevent disputes from escalating, thus contributing to overall project efficiency.

As noted by MacGregor and Maclay (2017), expert determination stands out for its cost-effectiveness and expeditious nature, particularly when compared to litigation or arbitration. Additionally, it delivers a conclusive and binding resolution to disputes, typically resistant to challenges or appeals, thus contributing to its overall effectiveness and cost-effectiveness.

Disadvantages of current dispute resolution methods

While various dispute resolution methods aim to provide efficient and affordable solutions, each has its own limitations. Litigation is often perceived as the least efficient due to its lengthy process and high costs, with Çevikbaş and Köksal (2018) noting that it can damage business relationships. Echtermach-Jaubert et al. (2021) further emphasise that litigation is risky and expensive, making it less desirable for most construction disputes unless necessary. Meanwhile, Abwunza et al. (2022) propose that unfavourable outcomes in arbitration often raise concerns about fairness, thereby undermining its effectiveness. The American Bar Association Section of Litigation (2013) further highlights a critical limitation of arbitration, primarily its restricted appeal options, intensifying its ineffectiveness and cost-ineffectiveness.

Thomas et al., (2013) found that in construction disputes, negotiations can stall because parties are unwilling to compromise, causing project delays and increased expenses. Yiu and Chung (2014) emphasise that, despite the complexities of the negotiation process, all participants share a common objective of achieving their desired outcomes, occasionally resulting in standstills or withdrawals, amplifying the ineffectiveness and cost-ineffectiveness of negotiation in construction disputes.

Kaming et al., (2013) identified a limitation of mediation in construction disputes where the mediator lacks the authority to enforce agreements reached by the parties during the mediation process. Umar and Chauhan (2016) express concerns about the impartiality of mediation, particularly when the

mediator has prior connections with one of the parties or a vested interest in the dispute's outcome, accentuating doubts about its effectiveness and cost-ineffectiveness.

The financial considerations of introducing Dispute Adjudication Boards (DABs) in the preliminary stages may render them less suitable for smaller construction projects. A significant drawback of DABs is that their rulings lack the enforceability typically associated with arbitration awards or court judgments, as highlighted by Abeynayake and Weddikkara (2018). This limitation can hinder their effectiveness and cost-effectiveness.

Puteri et al. (2020) outlined several drawbacks associated with expert determination, including limited avenues for appeals, which can constrain the effectiveness of the process, and the absence of legal backing, potentially impacting its cost-effectiveness and reliability. Expert determination may also have limited suitability for disputes centered on factual matters. Additionally, there might be uncertainty surrounding the categorisation or positioning of issues, potentially hampering both its effectiveness and cost-efficiency. Moreover, the method is best suited for technical disputes, limiting its effectiveness in cases involving broader legal or contractual issues.

The review has conducted an in-depth analysis of crucial factors that affect both the effectiveness and affordability of these dispute resolution approaches. This information provides construction industry professionals with the means to enhance the effectiveness of their dispute resolution processes. In the forthcoming chapter, we will delve into the research methodology utilised in this study. This chapter will furnish a comprehensive outline of the research design, techniques for data collection, and analytical methods employed to gain a deeper understanding of construction dispute resolution, presenting a practical guide for the subsequent empirical research.

Research Methodology and Method

Research paradigm

The data for this study was collected from registered quantity surveyors who possessed practical experience with disputes in the built environment. As a result, the epistemological foundation of this research is rooted in Authoritative knowledge, while its ontological foundation is grounded in Objectivism.

The research adhered to a positivist approach due to its focus on empirical evidence, objectivity, and the systematic application of scientific methods, which established a robust framework for the investigation and attainment of knowledge. Prioritising observable facts and impartiality, positivism offered a reliable basis for gaining knowledge through the utilisation of scientific methodologies.

Research design

This research employed a deductive approach, conducted an online survey, adopted a mono-method research design, and operated within a cross-sectional time to examine the primary causes of disputes, the most efficient dispute resolution method, and the most cost-effective dispute resolution method.

The online questionnaire consisted of four sections. The first section gathered information about the participants' demographics. The second and third sections included scaled-response questions that pertained to the research's existing literature, aiming to identify the main causes of disputes and the most effective dispute resolution method. The fourth section was dedicated to investigating the dispute resolution method's cost-effectiveness.

Data collection method

The research targeted a specific group, namely registered professional quantity surveyors operating in South Africa who are also registered members of the Association of South African Quantity Surveyors (ASAQS). Responses were gathered from fifty-four quantity surveyors.

With ethical clearance approval, the Association of South African Quantity Surveyors (ASAQS) was approached to distribute a survey link on their website and via the Weekly Newsletter. The survey remained accessible for five consecutive weeks and was additionally promoted through the ASAQS

weekly newsletter. Furthermore, it was shared on LinkedIn, and direct messages were sent via LinkedIn to professional quantity surveyors. Following this outreach, the data collected was compiled and converted into a spreadsheet for subsequent analysis. Before commencing the analysis, any duplicated or incomplete responses were excluded from the dataset.

Data analysis

The collected data was subjected to a descriptive statistical analysis, and the mean was employed to interpret the gathered information. Specifically, mean values were calculated for the main causes of dispute among the listed factors, the most effective dispute resolution method within the common methods, and the most cost-effective dispute resolution method within the common methods. These mean values played a crucial role in pinpointing the prevailing cause of disputes, the most effective dispute resolution strategies, and the most cost-efficient dispute resolution method in the construction domain.

Research Results

The demographic information from the survey respondents provides valuable insights into the composition of the sample. In terms of gender, the majority of respondents were male (69%), comprising 69%, while 31% were female. Regarding age distribution, the respondents varied in age, with the highest representation in the age group of 31 to 40 (44%). The highest qualification held by respondents was predominantly an honours degree (76%), followed by those with an undergraduate degree (11%) and a master's degree (9%). Notably, there were no respondents with a PhD degree. The years of experience working as a Professional Quantity Surveyor (PrQS) were diverse, with 26% having more than 20 years of experience, while 31% having less than 5 years of experience. Finally, in terms of the sector, a significant portion (39%) worked in the private sector, 26% were from the public sector, while 35% participated in both public and private sectors.

The most efficient dispute resolution

Figure 1 illustrates the prior engagement of participants in the construction industry with various dispute resolution methods. These results are evaluated by using the mean scores.

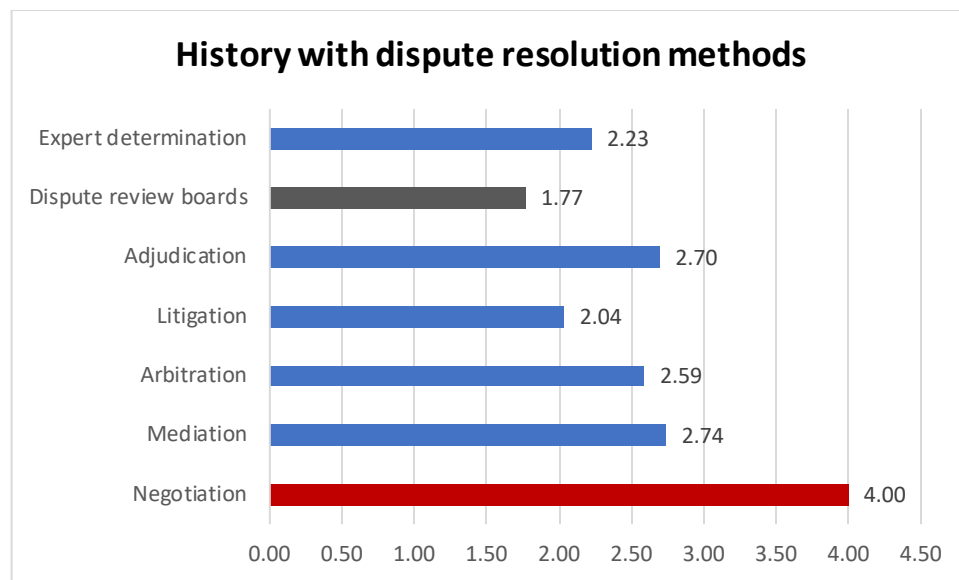


Figure 1: Respondents' history with dispute resolution methods

The past involvement of respondents within the construction industry with various dispute resolution techniques reveals distinct trends. With a mean score of 4.00, negotiation stands out as the most frequently utilised method, highlighting substantial prior involvement. Mediation follows with a mean score of 2.74, suggesting significant but somewhat less frequent use. Arbitration, with a mean score of 2.59, falls into the category of methods with moderate historical usage. In contrast, litigation, scoring

2.04 on average, shows a lower level of past engagement. Adjudication, with a mean score of 2.70, closely aligns with mediation in terms of historical utilisation and surpasses litigation. On the other hand, Dispute Review Boards seem to have been employed less frequently, receiving a mean score of 1.77. Expert Determination falls into the moderate category, recording an average mean score of 2.23.

Figure 2 displays the dispute resolution methods that respondents consider most efficient. The assessment of these results is based on the p-value and eta-squared scores.

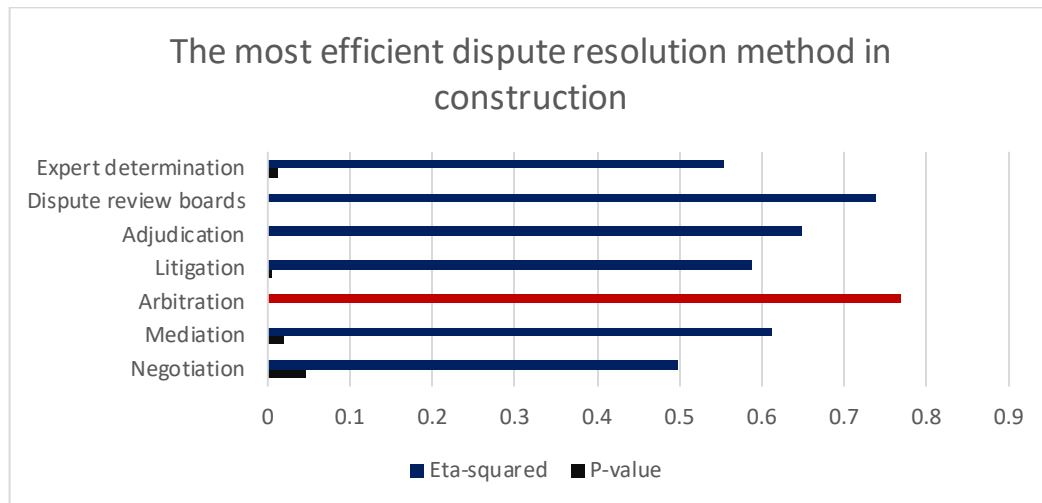


Figure 2: Most efficient dispute resolution method

The assessment of the efficacy of different dispute resolution methods shown in Figure 2 reveals some interesting insights. Collectively, methods with highly significant p-values (< 0.001), notably arbitration, adjudication, and dispute review boards, presented robust evidence of effectiveness disparities. Considering effect size (η^2) was crucial to interpret practical significance comprehensively.

The ANOVA results affirm substantial differences in the efficacy of dispute resolution methods in construction, substantiated by their p-values. Arbitration, adjudication, and dispute review boards are particularly impactful, suggesting substantial variations in perceived effectiveness. Eta-squared values underscore this, where arbitration elucidates 76.8% of the variance, and dispute review boards contribute approximately 73.8%. These values emphasise these approaches' comparatively more considerable influence on dispute resolution effectiveness. The substantial Eta-squared of 0.768 for arbitration signifies that approximately 76.8% of the variance in effectiveness is attributed to the method used, further highlighting the significance of arbitration and dispute review boards in construction dispute resolution and their substantial contributions. The results suggest that arbitration is the most efficient dispute resolution method, surpassing dispute review boards based on their superior effect sizes.

The most affordable dispute resolution method

Figure 3 illustrates the dispute resolution methods that the respondents deem the most affordable. The evaluation of these results relies on the p-value and eta-squared scores.

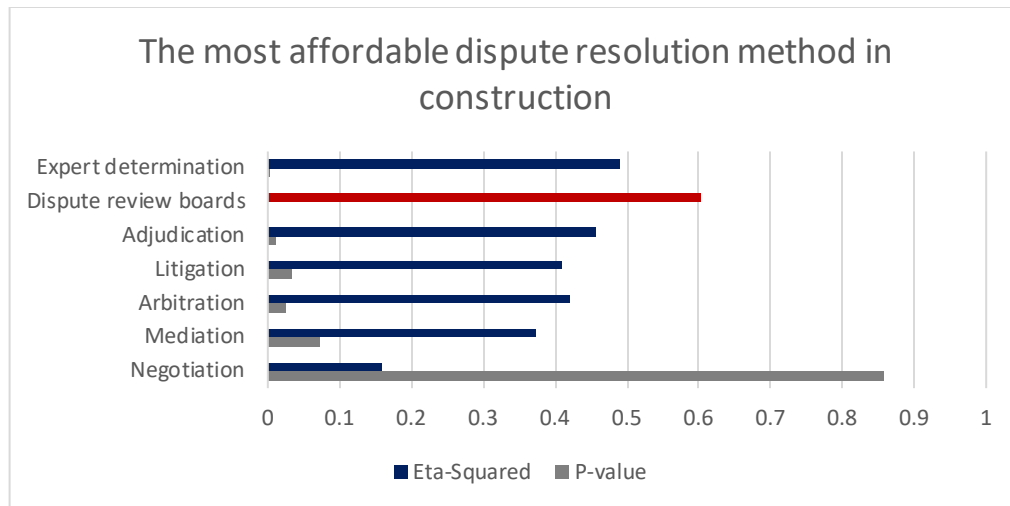


Figure 3: Most affordable dispute resolution method

In the evaluation of the affordability among diverse dispute resolution methods, Dispute Review Boards surfaced as the most influential method, boasting an Eta-squared of 0.602 and a highly significant p-value of < 0.001 . Expert Determination also exhibited statistical significance and a substantial effect (Eta-squared: 0.489, p-value: 0.004), enriching the spectrum of methods available for achieving cost-effectiveness. These results provide valuable insights for professionals in the field, assisting them in making informed decisions when choosing the most appropriate and affordable dispute resolution method for construction projects.

The open-ended question seeking input on the cost-effectiveness of construction dispute resolution methods yielded a solitary but insightful response. The respondent emphasised the affordability of negotiation, particularly when it involves collaboration between the client, consulting team, and contractor, provided that the client is open to this approach. They also noted that public clients sometimes avoid negotiation due to concerns about audit procedures, preferring more strictly regulated processes. While this cautious approach has its merits, it might result in higher long-term costs for the government. Despite the limited number of responses, these insights highlight the intricate factors involved in assessing the cost-effectiveness of construction dispute resolution methods.

Discussion

The ANOVA analysis thoroughly examined the efficiency regarding dispute resolution methods, arbitration, adjudication, and dispute review boards emerged as highly impactful, challenging the hypothesis that negotiation is the most effective. Arbitration, notably, demonstrated the most significant impact. Dispute review boards, adjudication, and arbitration played substantial roles concerning cost-effectiveness, with dispute review boards being identified as the most influential method.

In summary, arbitration emerges as the most efficient means of resolving disputes, while dispute review boards are the cost-effective method, surpassing negotiation, and mediation. These findings provide valuable insights for industry professionals, guiding informed decision-making in dispute resolution for construction projects.

To gain insight into the viewpoints of industry professionals, participants expressed their worries and preferences concerning dispute resolution methods. Foremost among their concerns were the perceived high costs and time-consuming nature of these methods. In contrast, less significance was attached to concerns related to the perceived informality and lack of structure in alternative dispute resolution methods, as well as doubts about the potential for achieving fair or satisfactory outcomes.

Conclusion

The analysis revealed that arbitration is the most efficient method for resolving construction project disputes, while dispute review boards are the most cost-effective. Contrary to the initial hypothesis

favouring negotiation, arbitration demonstrated superior impact in efficiency, and dispute review boards surpassed other methods in cost-effectiveness. Industry professionals highlighted concerns about high costs and time demands, with less worry about informality and fairness. These insights guide stakeholders in selecting effective and economical dispute resolution methods, with arbitration and dispute review boards emerging as superior choices.

Recommendations

The recommendations target various stakeholders within the construction industry. Quantity surveyors are advised to highlight the importance of investing in dispute resolution training, with a particular focus on Arbitration and Dispute Review Boards (DRBs) due to their proven effectiveness in delivering efficient and affordable dispute resolutions. Continuous learning about industry trends ensures that quantity surveyors stay informed about emerging dispute resolution methods, empowering them to make informed decisions in diverse construction project scenarios. The Association of South African Quantity Surveyors (ASAQS) should consider enhancing professional development, advocating best practices, fostering collaboration with tertiary institutions and industry partners, and creating a centralised resource hub for dispute resolution support. Tertiary institutions offering construction-related programs should consider reinforcing coursework related to dispute resolution and promote research and case studies focused on construction disputes to equip future professionals with practical knowledge and contribute valuable insights to the industry.

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Promoting Construction Education in South Africa: a Single Case Study of the DSI/NRF Research Chair

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Abstract

The importance of construction education cannot be overemphasised in the South African construction industry. Continuous education, training and learning are of great necessity to young construction professionals. Using a case study approach, this study aims to examine the research boot camp organised by the DSI/NRF Research Chair in Sustainable Construction Management and Leadership in the Built Environment. The study reveals a diverse racial composition of the research bootcamp comprising various young professionals from countries like South Africa, Nigeria, Ghana, and others. The boot camp taught participants both hard and soft skills related to research skills, data analysis, language familiarity with academic software, subject matter expertise, time management, and emotional intelligence. Furthermore, the research boot camp aligns with the Africa Agenda 2063, the National development plans of South Africa, and the Sustainable Development Goals 4,5 and 10. This study is important in understanding the competitive advantage the construction industry can gain and the sustainability it can achieve by developing young professional's competencies. There is a need for the construction industry to be involved in supporting more of this research boot camp to foster self-actualisation, engagement, and resilience and help young professionals stay abreast of the latest developments in the industry. Also, there is a need for more of this approach to learning and training across race and gender, which is supported and promoted by the construction industry in line with the Skill Financing Act. This study aligns with the conference's skill development and human resource management theme.

Keywords: Construction Education, DSI/NRF, Boot Camp, Hard and Soft Skills, Construction Industry.

Introduction

The educational history of the ancient civilisation included important developments for later education systems, giving rise to the need for curriculum and schools. Furthermore, schooling (a formal education system that takes place in schools, universities, etc.) can be referred to as the purposeful selection of curriculum content, as well as the instructional method applied in content teaching (Gutek,2022).

The evolution of technology from the First Industrial Revolution through to the Fourth Industrial Revolution, which provides the framework for Construction 4.0, has resulted in skills-related issues across diverse backgrounds. These skills-related issues, which could be in the form of skills gaps, skill mismatches, and skill shortages (Boswell et al.,2004; Aigbe et al.,2019; Adepoju et al.,2022) have led to the need for construction education in order to satisfy the skill requirements of the present age. This was put succinctly by Jerry Rubin: “Jobs are available for young professionals, but traditional education alone will not suffice; a new training method is required that meets modern day requirements” (adapted quote)

Gutek (2022) referred to education as the formal process of instruction that takes place in institutions such as schools and universities (apart from the informal processes of enculturation by society), etc. This formal education could be within the classroom (on-site), or outside the classroom (off-site). Education is the cornerstone of human development and progress, which is essential for developing individuals' knowledge, skills and character (Ashikuzzaman,2023). According to Cassady and Kozlowski (2008) the combination of concrete experiences with active experimentation optimises learning. Consequently, formal learning goes beyond classroom learning but includes knowledge

gained through lectures, seminars, presentations of course assignments, training, and educational field trips (Menkshi & Braholli,n.d).

The DSI/NRF research boot camp, which is a non-traditional approach to learning, was meant to train young professionals across diverse professions, races, and genders in both hard and soft skills relevant to modern-day needs. Berridge et al. (2020) stated that boot camps play a significant role in skills improvement and boost confidence in skills and knowledge application. Schatte et al. (2019) further highlighted the importance of boot camps as preparing and improving students' confidence, helping in professional identity formation, and enabling educators to address some missing links in the curriculum. This study, therefore, aims to appraise the DSI/NRF research boot camp with a view to using it as a case study of how young professionals (especially young quantity surveyors) can be continuously developed beyond the traditional ways of learning. This will help foster the spirit of continuous learning among young professionals in the construction industry and help meet the skill needs of employers in the digital era.

Literature Review

Technological advancement has shortened skills shelf life and affected the requirements of employers (World Economic Forum, 2016). This calls for the need to examine the competencies required, competencies available, and measures aimed at addressing these issues, which includes building and developing skills and retraining (Cotten,2007; Shukla,2009). Short and Keller-Bell (2019) opined that the skills that will be relevant in the future will be a combination of hard and soft.

Hard and soft skills

Skills can be classified into hard and soft skills; soft skills include teamwork and communication skills, while hard skills include technical skills (Ejohwomu,2007). The future skills required in the twenty-first century will be a combination of both hard and soft skills, such as skills related to teamwork, goal-achieving, self-awareness and management. and digitalization (Short & Keller-Bell.,2019; Horvathova et al.,2022). In order to meet the skill requirements of young construction professionals within the academic environment, adopting the traditional approach to learning only will not suffice, but the adoption of a non-traditional approach to learning, such as the boot camp approach, will be of great benefit as it enables educators to address some missing links in the curriculum.

Boot camp

A boot camp can be referred to as an intense education program which involves the transmission of vital knowledge and the training of professionals to meet needs and demands in a short time required by the labour market or an organisation (Virgen et al.,2020).A boot camp can be used to provide instructions and hands-on practice of skills. This involves the provision of training to participants which could be described as reskilling or upskilling training. Reskilling can be referred to as role transitioning by learning new competencies, while Upskilling can be referred to as gaining new skills to aid the current job responsibilities/position, which involves continuous learning and education, curriculum review (World Economic Forum,2018; Li et al.,2022; Anunobi &Ukwoma,2009; Olughor,2023; Aigbe et al.,2024) etc.

The traditional approach to learning, unlike the Non-traditional approach is abstracted in relation to the knowledge and skill learned; the Non-traditional approach to learning involves; observation of expert by students,coaching,conceptual scaffolding, articulation of task knowledge and understanding, and exploring diverse ways of knowledge and skills usage(Shuell,2001)

Methodology

Research subject

The DSI/NRF Research Boot Camp was organised by the DSI/NRF Research chair in Sustainable Construction Management and Leadership in the Built Environment at the University of Johannesburg, South Africa. The event was held at the Gallagher Hotel Midrand, Johannesburg, from the 21st of April to the 24th of April 2024, in South Africa. Participants for the Research Boot Camp, who were mostly

postgraduate students, were selected for the event based on their expression of interest in participating in the boot camp and a commitment to adhere to the camp rules.

Method

A case study approach was adopted for this study because it allows for an in-depth investigation of a contemporary phenomenon in a real-life context (Schoch,2020). A case study involves telling stories about something unique about an organisation. Furthermore, the study stated that a case study can be descriptive, exploratory or explanatory (Tasci et al.,2020). This study adopts a case study approach to appraise the DSI/NRF research boot camp with a view to using it as a case study of how young professionals (especially young quantity surveyors) can continuously develop beyond the traditional ways of learning. The case study approach is appropriate for this study because of the flexibility to investigate the educational methods and the rich, contextual insights into the learning process, which provide their impacts on participants' skills development compared to a quantitative method. A purposive sampling technique was employed for this research because it helps provide insight into the actual event being studied, allows for in-depth focus on the phenomenon, and allows for the exploration of information-rich cases (Schoch,2020). Furthermore, purposive sampling techniques were employed for this study to ensure that only those students who expressed interest in the boot camp and a commitment to adhere to the camp rules were selected. The study involves a single case and participants for the Research Boot Camp, who were mostly postgraduate students and were initially selected for the event based on their expression of interest in participating in the boot camp and a commitment to adhere to the camp rules. The final participants of Ninety (90) postgraduate students were chosen based on being a student of the DSI/NRF research chair, registration for the bootcamp and actual attendance at the event, thereby allowing for diverse representation.

The case study approach adopted for this study involves collecting data through participant observation, and field notes were collected using semi-structured approach (which centred around the objectives of the study which were in line with the pre-determined theme of the boot camp and other themes of interest to the researcher which were validated by expert reviewers to ensure alignment with the objectives of the research) and in addition to the participant observation and semi-structured field notes, the semi-structured one-on-one interview was conducted with some participants to get their individual perspectives and perceptions (feedback). Knott et al. (2022) stated that the estimated sample size can be obtained by drawing on previous saturation reports, which are usually between 12 and 20. Therefore, the sample size for this semi-structured interview was put at 20 participant

The case study data analysis involves reading and reviewing all data collected (including field notes) and the confirmation of the observations recorded by researchers (for data validation); data were also reviewed for theme discovery, which involves the identification of recurring themes and patterns within the observed data, i.e. thematic analysis (Braun & Clark,2006; Tasci et al.,2020), coding, making comparisons across various themes, and reporting.

Result, Discussion and Conclusion

DSI/NRF research boot camp (Participant observation)

The DSI-NRF Research Chair in Sustainable Construction Management and Leadership in the Built Environment organised an intensive Research Bootcamp from April 21-24, 2024. The Boot Camp brought together ninety (90) master's and PhD students of diverse professions, races, and genders from the Research Centre, significantly enhancing and developing their research capabilities. The racial composition of the participants was made up of students from South Africa, Nigeria, Ghana, Uganda etc. Also, in contrast to the popular male dominance of construction-related events, there was a remarkable participation of women. The professional composition of participants at the boot camp were Quantity surveyors, Builders, Engineers, Construction managers, etc the event was held off the four walls of the classroom and was held in a non-traditional classroom setting. The activities engaged in at the research boot camp aligned primarily with upskilling and, to some extent, reskilling in order to develop the hard and soft skills of young construction professionals.

Upskilling and reskilling activities

The future skills required in the twenty-first century will be a combination of both hard and soft skills such as effective teamwork skills, goals-achieving skills, self-awareness, and self-management skills, as well as digital skills geared toward meeting specific needs such as creative and innovative problem solving, as well as knowledge and skills application (Short & Keller-Bell, 2019; Horvathova et al., 2022)

The research boot camp provided an opportunity for the upskilling and reskilling of the participants, and the activities engaged in at the research boot camp included **Presentation skills training:** Students' presentation skills were honed through a comprehensive session on creating effective presentation slides and mastering the science of communication. This is in line with the need to build competencies on how to communicate scholarly research findings on issues related to the digitalisation of the construction industry. **Research skills training:** The students received extensive training on several critical research aspects, including writing comprehensive literature reviews and understanding the fundamentals of formulating research problem statements and research questions. They were guided on identifying research gaps and grasping the concept of research methodology. This is in line with the build skills relevant to proffering scholarly solutions to nagging construction digitalisation challenges. **Article/ Abstract Writing Hackathon:** This was meant to further build the research prowess of the participants by engaging them in developing scholarly research articles that proffer both theoretical and empirical solutions to the construction industry. Language familiarity with academic software, subject matter expertise, time management, and emotional intelligence. Other activities meant to support and build the participants were the UJ/NRF scholarship opportunities for eligible participants and the sharing of research expertise by a renowned scholar.

By the provision of training in both hard and soft skills, participants developed the requisite competencies needed to thrive professionally and further succeed in the world of work in the digital era, thereby laying credence to its comprehensiveness to professional development.

Participants perspective (Semi-structured interview)

Knott et al.(2022) stated that the estimated sample size can be obtained by drawing on previous saturation reports, which are usually between 12 and 20. Participants for the semi-structured one-on-one interview were randomly selected for the study, and saturation for the study was reached with seven (7) participants as there was no new information derived from the interview due to the non-complexity of the research topic, objectives, and similarity of participants, and pre-defined theme, this aligns with Saunders et al. (2017) which stated that saturation is reached when there is no new information by new data.

All the participants agreed that the research boot camp provided them with the opportunity to upskill and reskill through activities such as Presentation skills training, Research skills training, and Article/ Abstract Writing Hackathon. According to some of the participants,

"I have been struggling on how to identify research gap"- Participant 7

"Presenting at the boot camp has boosted my confidence, and I am now more confident"-Participant 2

"Working together in a group to generate a research abstract in the boot camp, has broadened my writing skills"-Participant 4

All the participants agreed that the Non-Traditional approach of learning and teaching (the boot camp) was highly effective as it provided a hands-on approach to learning that involved industry experts and critical thinking. According to some of the participants

"Wow, this approach to learning was so relaxing and fruitful"-Participant 1

"The opportunity to make a presentation and receive immediate feedback, as well as write an article was quite academically empowering"-Participant 5

"The opportunity presented by research bootcamp to network provided another form of learning" - Participant 3

Despite these, participants also unanimously agreed that there was a need for improvement in time allocation to activities, engagement of more industry practitioners, and engagement of more digital technologies.

Alignment with international and national goals

This study on the DSI/NRF research boot camp aligned with both the **Sustainable Development Goals 2030 and the Africa Agender 2063**.

Sustainable Development Goals 2030: This study aligns with the 2030 Sustainable Development Goals which include;

- a.) **SDGs 4:** This Goal speaks to fostering inclusive and equitable quality education and lifelong learning for all (United Nations,2024). The Research Bootcamp, which is a non-traditional way of education, brought together construction professionals of diverse backgrounds in terms of race, gender, and occupation.
- b.) **SDGs 5:** This Goal speaks to promoting gender equality and empowering women and girls (United Nations,2024). The Research Bootcamp brought together females across different age brackets to empower them with relevant hard and soft skills related to the technological era.
- c.) **SDGs 10:** This Goal speaks to inequality reduction within and among countries (United Nations,2024). The Research Bootcamp brought together professionals from diverse countries of origin, including South Africa, Nigeria, Ghana, Uganda, etc. It also brought together different ethnic groups within these countries.

Africa Agender 2063: This study aligns with the Africa Agenda 2063 Aspiration and Goals such as;

- a.) **Aspiration 1, Goal 2:** Well-educated citizens and revolution in skills hinged on Science, Technology, and Innovation(*African Union*, n.d; Ufomba,2020). These were the core of the Research Bootcamp, which was anchored on education and skills development.
- b.) **Aspiration 6, Goals 17 and 18:** Full Gender equality, as well as engaged and empowered youth and children (*African Union*, n.d; Ufomba,2020). The Research Bootcamp brought together diverse construction professionals of diverse ages and genders for empowerment in both hard and soft skills.



Figure 1: Aspects and Objectives of Agenda 2063, adopted from Ufomba (2020)

Alignment with National Policies/Acts of South Africa

- a.) **The Skill Development Act 97 of 1998:** Aigbavboa et al. (2016) stated that the goals of the SDA include inter alia: developing South African workforce skills, promoting employer and worker participation in learning programmes, and improving the employment prospects of persons previously disadvantaged by unfair discrimination and redressing those disadvantages through training and education. The categories of students in the Research Bootcamp include those students who are employed within the Universities in South Africa (i.e. the University of Johannesburg, Walter Sisulu University, etc) and those outside the University system which aligns with the purpose of the SDA of developing South African workforce skills. The same aligns with the National Development Plan 2030 of South Africa.

Conclusion

The importance of construction education cannot be overemphasised in the South African construction industry. Continuous education, training and learning are of great necessity to young construction professionals. The DSI/NRF research boot camp, which is a non-traditional approach to education, deviates from the traditional mode of education and learning done in the classroom. The boot camp brought together construction professionals from diverse backgrounds related to race, gender, etc. The observatory approach and the use of interviews reveal that activities at the boot camp included skills development, which involved reskilling and upskilling through activities such as research, presentation skills training and article/abstract writing hackathon. These activities align with the Sustainable Development Goals and the African Agenda 2063. Further research can be carried out as regards boot camp using other methodologies apart from the case study approach.

Recommendation

Based on the discussions and conclusion of the study, there is a need for the following recommendations

- a.) Curriculum Review: A hybrid model of learning should be encouraged that is a Non-traditional approach to learning should also be prioritised as a way of training construction professionals together with the traditional method of learning (Curriculum review).
- b.) Inclusive Recruitment: In the course of recruiting students into institutions, diversity should be emphasised in terms of race, gender, and occupation. This will lead to future Research Bootcamps being more diversified and fostering a more equitable construction education
- c.) Future-focused skill development: There is a need for more of this approach to learning and training across races and genders supported and promoted by the construction industry in line with the Skill Financing Act.
- d.) Industry Partnership: There is a need for the construction industry to be involved in supporting more of this research boot camp to foster self-actualisation, engagement, and resilience and help young professionals stay abreast of the latest developments in the industry.

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Quantity Surveying Lecturers' Insights into Student Engagement Dynamics

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Abstract

This study investigates the factors influencing student engagement in higher education, focusing on lecturers in the Bachelor of Science (Quantity Surveying) Honours program at Nelson Mandela University, South Africa. The research aims to construct a Systems Influence Diagram (SID) that encapsulates the perspectives of Quantity Surveying lecturers regarding key drivers of student engagement, which is essential for academic success and persistence. The objectives include identifying primary engagement drivers and exploring their interconnections as perceived by the lecturers. The study uses an interpretivist paradigm to capture participants' subjective experiences through a qualitative design. Data were collected via focus group discussions and individual interviews, combining inductive and deductive reasoning to develop a comprehensive understanding of student engagement dynamics. An Interactive Qualitative Analysis (IQA) approach was central to creating the SID, visually representing the various influences. The study identified 37 factors grouped into seven thematic categories: departmental influences, external factors, group dynamics, lecturer characteristics, motivation, personal attributes, and skills. The SID highlighted departmental influences as the primary driver, with lecturer characteristics, external factors, and personal attributes as secondary contributors. These findings were confirmed through semi-structured interviews, reinforcing the multidimensional nature of student engagement, shaped by institutional structures, lecturer interactions, and individual student attributes. The study's small sample size may limit the generalizability of the findings. The practical implications suggest a collaborative approach involving departments, lecturers, and students, supported by external policies, to foster an engaging educational environment. Such a holistic strategy can enhance student attentiveness, motivation, and participation, leading to improved academic outcomes. This paper introduces a SID to highlight the key role of departmental leadership in driving student engagement in Quantity Surveying education. It advocates for holistic strategies integrating institutional and external support, aligning with the conference theme and offering practical solutions for adapting QS education to future challenges.

Keywords: Student Engagement; Quantity Surveying Lecturers; Interactive Qualitative Analysis.

Introduction

"Education is not the filling of a pail, but the lighting of a fire" (Yeats, 1924). This quote by William Butler Yeats, one of the foremost figures of 20th-century literature, suggests that education should not be viewed as a mere transfer of information, like pouring knowledge into a container. Instead, it should be seen as a process of igniting curiosity, passion, and independent thought within learners. The metaphor of "lighting a fire" emphasises the idea that true education inspires students to think critically, explore new ideas, and develop a lifelong love of learning rather than just memorising facts. This statement underscores the transformative potential of education, where true learning ignites curiosity and passion rather than merely transferring information. In modern higher education, particularly in Quantity Surveying (QS), student engagement has emerged as a critical determinant of educational quality and student success. Defined as the investment of cognitive, emotional, and behavioral energy in academic activities, student engagement has been linked to enhanced learning outcomes, critical thinking development, and retention (Fredricks, Blumenfeld & Paris, 2004; Trowler, 2010). Engaged students consistently achieve better academic results, exhibit deeper problem-solving abilities, and develop stronger connections to their field of study (Kahu & Nelson, 2018; Zepke & Leach, 2010). However,

despite its recognised importance, sustaining high levels of engagement remains a persistent challenge across diverse educational contexts (Kuh, 2009; Biggs & Tang, 2011).

Previous research has thoroughly examined the multifaceted nature of student engagement, recognising that it encompasses cognitive, emotional, and behavioural dimensions, all shaped by institutional, social, and pedagogical factors (Krause & Coates, 2008; Kahu, 2013). This body of work consistently highlights the significance of student engagement in academic achievement. For example, Ma and Wei (2022) demonstrated that engagement mediates the relationship between classroom climate and academic performance, emphasising the importance of a positive learning environment. Similarly, Fredricks *et al.* (2004) and Zhao, Zheng, Pan and Zhou (2021) found that internal factors, such as self-esteem, significantly boost engagement levels, enhancing academic outcomes. Kuh (2009) further positioned engagement as a key predictor of student success, with high levels of engagement in educational activities directly correlating to better academic performance. While these studies have provided a solid foundation, they have primarily focused on the student perspective, often overlooking how lecturers perceive and influence engagement. Additionally, while external factors such as institutional support have been explored, the interaction between internal student attributes and these external factors remains under-researched, particularly within specific academic programs like Quantity Surveying. This omission creates a critical gap in understanding how student and lecturer perspectives converge to shape engagement in discipline-specific contexts.

On the other hand, while there is no shortage of studies examining student engagement, few have holistically explored the interaction between internal and external factors in engagement within the QS discipline. Even fewer studies have considered the insights of lecturers, whose experiences offer valuable context for understanding the systemic and pedagogical challenges in fostering engagement. Addressing this oversight is crucial, as failure to integrate lecturers' perspectives into engagement research may result in incomplete strategies for improving student outcomes. If these gaps remain unresolved, the effectiveness of interventions to improve engagement could be severely limited, potentially leading to continued disengagement and suboptimal academic performance within QS programs.

This study aims to fill this gap by examining the factors influencing student engagement from the perspective of QS lecturers at Nelson Mandela University. This research provides a more comprehensive understanding of engagement dynamics by constructing a Systems Influence Diagram (SID) that integrates both internal and external factors. The practical significance of this study extends beyond mere academic interest—it has the potential to inform policy development and the creation of targeted interventions that foster engagement and improve student success in QS programs. The specific objectives of the research are as follows:

- Objective 1: To establish the factors that influence student engagement according to QS lecturers.
- Objective 2: To identify the relationships between the factors influencing student engagement.

The findings of this study will contribute to both academic research and practical application within higher education, particularly in the context of QS programs. By identifying the key factors influencing student engagement and elucidating the relationships between these factors, this research offers a comprehensive framework that educators and administrators can use to enhance student engagement. The construction of the SID provides a visual representation of these complex dynamics and serves as a practical tool for decision-making. Improving student engagement is not merely an academic exercise but a critical initiative that has far-reaching implications for student success, retention, and overall educational outcomes. The insights gained from this study will inform the development of more effective teaching strategies and foster supportive learning environments, ultimately contributing to the production of well-prepared graduates for professional practice.

This paper begins with a comprehensive literature review that examines the existing research on student engagement, highlighting the key internal and external factors and the gaps that this study aims to address. The methodology section then outlines the research design, including using the Interactive Qualitative Analysis approach and constructing the Systems Influence Diagram. The results section presents the factors identified by Quantity Surveying lecturers and the relationships between them, as visualised in the SID. The following discussion interprets these findings in the context of the broader literature, offering insights into how they can be applied to enhance student engagement in Quantity

Surveying programs. Finally, the conclusion summarises the key contributions of the study, discusses its limitations, and suggests directions for future research.

Literature Review

Conceptualising student engagement in higher education

Student engagement in higher education is a multifaceted construct essential for academic success, encompassing cognitive, behavioural, and affective dimensions. Cognitive engagement refers to the mental investment and effort students put into their learning processes. This dimension is a significant predictor of academic achievement. Achdiyah, Latipun and Yuniardi (2023) found that cognitive engagement enhances learning outcomes by enabling students to employ effective learning strategies and make informed decisions about their academic activities. Additionally, Khan, Gul and Zeb (2023) support the notion that cognitive engagement positively correlates with academic success, as it fosters deep processing and the effective application of knowledge to new situations. These findings suggest that cognitive engagement contributes to immediate academic success and the development of long-term learning strategies vital in higher education contexts. Thus, fostering cognitive engagement is crucial for students' academic achievement and overall learning development.

Behavioural engagement refers to the visible and measurable actions students take in their academic environment, such as attending classes and participating in discussions. Boateng and Kalonde (2024) noted that behavioural engagement can be enhanced through structured and interactive activities that provide clear guidance and opportunities for student interaction. However, the research also indicates that behavioural engagement alone may not predict learning outcomes effectively, particularly if it lacks the depth of cognitive involvement. While behavioural engagement is an important indicator of student involvement and commitment, it must be supported by cognitive engagement to result in meaningful learning outcomes. Structured activities encouraging behavioural and cognitive engagement are crucial for optimising student outcomes. In light of this, educators should design learning environments that integrate behavioural and cognitive dimensions to enhance student engagement effectively.

Affective engagement encompasses students' emotional responses to their learning experiences, including feelings of interest, enthusiasm, and belonging. Laranjeira and Teixeira (2024) demonstrated that positive affective engagement is associated with better academic performance and well-being. Moreover, Khan *et al.* (2023) found that emotional engagement fosters a deeper connection to the learning material, which is essential for sustained academic success. This emotional connection improves immediate academic outcomes and supports long-term engagement and persistence in higher education. Addressing the emotional aspects of learning helps educators better support students in maintaining high levels of engagement and reducing the risk of burnout. Therefore, incorporating strategies that enhance affective engagement is vital for fostering motivation and persistence in higher education.

The multidimensional nature of student engagement necessitates a comprehensive approach that integrates cognitive, behavioural, and affective strategies. This approach recognises the dynamic and context-dependent nature of engagement and the need for tailored instructional strategies that address the diverse needs of students. Educators can better support student outcomes and well-being in higher education by adopting a holistic approach to engagement, ensuring a more fulfilling and effective learning experience. Therefore, future research and practice should continue to explore and refine strategies that address all dimensions of student engagement to optimise educational success.

Internal and external factors influencing student engagement

Student engagement is a complex construct influenced by a myriad of internal and external factors, each playing a crucial role in shaping how students interact with their educational experiences. Understanding these influences is vital for educators aiming to foster effective and supportive learning environments. This comprehensive overview explores the internal factors, such as personal attributes, skills, and self-regulation, alongside external factors, including departmental influence, group dynamics, and lecturer characteristics, collectively determining student engagement.

Internal factors influencing student engagement

Self-Efficacy and Intrinsic Motivation: Student engagement is significantly influenced by internal factors such as self-efficacy and intrinsic motivation. Research indicates that students with high self-efficacy are more likely to engage deeply in academic tasks as they perceive themselves as competent and capable, which enhances their motivation and persistence (Ghbari, 2024; El-Sayad, Saad & Ramayah, 2021). Furthermore, intrinsic motivation, driven by internal satisfaction rather than external rewards, is crucial for sustained engagement in learning activities. This is supported by Deci and Ryan's Self-Determination Theory, which posits that fulfilling basic psychological needs—autonomy, competence, and relatedness—enhances intrinsic motivation and, consequently, student engagement (Aleksovska-Velickovska, Gontarev & Kalac, 2019; Keller & Szakál, 2021; Reeve, 2012). Studies have shown that when students feel autonomous and competent, they are more likely to exhibit higher levels of emotional and cognitive engagement in their studies (Miao, 2023; Rothes, Lemos & Gonçalves, 2022). Therefore, fostering self-efficacy and intrinsic motivation within educational environments is essential for promoting effective student engagement.

Skill Development and Self-Regulation: Developing academic and social skills is crucial for enhancing student engagement, as these competencies enable students to effectively participate in educational activities, enriching their overall learning experience (Immanuella, 2023; Tian, Lu, Yin & Li, 2020). Additionally, self-regulation plays a significant role in maintaining student engagement, particularly when facing academic challenges. Research indicates that self-regulation strategies, including goal setting, self-monitoring, and reflection, are instrumental in helping students remain engaged (Oviawe, 2020). This aligns with findings that emphasise the need for educational strategies to incorporate training in self-regulation skills, equipping students with the necessary tools for sustained engagement and improved academic outcomes (Pan & Yao, 2023). Furthermore, fostering an environment that supports skill development and self-regulation can lead to enhanced motivation and academic success, highlighting the importance of these internal factors in the educational context (Holec & Marynowski, 2020; Wang, 2021).

External factors influencing student engagement

Institutional Support and Departmental Influence: External factors such as institutional support and departmental influence are pivotal in shaping student engagement. Research indicates that robust institutional support systems, particularly those focused on student-centred learning, create an environment conducive to higher engagement levels. Weerts and Hudson (2009) emphasise that quality resources and effective teaching practices significantly enhance student engagement. This aligns with Tinto (1997) foundational work, which underscores the necessity of comprehensive support structures in educational settings, especially in today's dynamic academic landscapes (Wilson, Summers & Wright, 2020). Furthermore, faculty support has been shown to positively impact both behavioural and emotional engagement, highlighting the importance of respectful and caring interactions between faculty and students, as noted by (Wilson et al., 2020). These findings suggest that educational institutions must prioritise the development of comprehensive support systems and foster positive departmental dynamics to maximise student engagement and improve academic outcomes (Beniston & Harris, 2017; Owusu-Agyeman & Amoakohene, 2021).

Group Dynamics and Social Interactions: The social context of learning significantly influences student engagement, particularly through positive peer interactions and collaborative learning. Vygotsky (1978) theory emphasises the importance of social interactions in learning, and contemporary research continues to validate this perspective. For instance, Sari, Liskinasih and Jansz (2023) demonstrate that collaborative group dynamics enhance student engagement by fostering a sense of belonging and mutual support. Additionally, Pérez-López, Gurra-Sarasa, Herrando, Hoyos, Bordonaba-Juste and Utrillas-Acerete (2020) highlight that peer interactions within technologically mediated environments can either enhance or challenge engagement, depending on the quality of these interactions and the effectiveness of the technological tools employed. This underscores the necessity for educational strategies that facilitate positive group dynamics and effectively integrate technology to support collaborative learning. Such approaches promote engagement and enhance critical thinking and problem-solving skills essential for academic success (Jamain, Putro & Sadewa, 2022; Gopinathan, Kaur, Veeraya & Raman, 2022).

Research Methodology and Method

The research philosophy guiding this study is grounded in interpretivism, an approach that emphasises the interaction between the researcher and the subject of research. Interpretivism acknowledges the subjective and multiple realities perceived by participants and recognises that research is inherently value-laden. This philosophical stance underpins the study's approach to understanding participants' complex and varied perspectives, highlighting the importance of the researcher's role in interpreting these perspectives within their specific contexts. Consequently, the interpretivist philosophy provided a foundation for the Interactive Qualitative Analysis (IQA) methodology employed in this study, aligning with the study's focus on exploring participants' subjective experiences.

The methodology for this study, influenced by systems theory, was Interactive Qualitative Analysis (IQA), as outlined by Northcutt and McCoy (2004). IQA was employed within a focus group setting to identify system factors, referred to as affinities, and to explore the relationships between these factors as articulated by the participants. By using IQA, the study generated data through an interactive, collaborative process, ultimately creating a System Influence Diagram (SID). This visual representation delineated the affinities and their interrelationships within a system of influence, reflecting the participants' direct experiences with the phenomenon under study. The use of IQA was well-aligned with the study's interpretivist philosophy, enabling the exploration of subjective realities through a structured, systematic approach.

The study began with an inductive data collection phase involving a focus group session with five Quantity Surveying (QS) lecturers. This session started with a guided imagery clarification exercise, followed by participants individually generating key thoughts in response to the issue statement, "What influences QS student academic engagement at Nelson Mandela University?" Each idea was recorded on a separate card, facilitating the identification of key factors influencing student engagement. The inductive nature of this phase allowed participants to express their thoughts without the constraints of predefined categories, thereby capturing a broad spectrum of influences. This focus group methodology was essential in identifying the initial affinities, setting the stage for subsequent coding and analysis processes.

Following the focus group session, the study progressed to the coding phase. Participants engaged in inductive and axial coding processes, collaboratively categorising the key thoughts into affinities (inductive coding) and assigning labels to these affinities (axial coding). A pro-forma affinity relationship table (ART) was then used for theoretical coding, enabling participants to assess the relationships between the affinities through a pairwise assessment. This coding process was crucial in organising the data into meaningful categories and exploring the perceived influences among these categories. The systematic approach ensured that the analysis remained grounded in the participants' experiences while allowing for the identification of overarching themes. The coding and analysis phase culminated in creating individual participants' SIDs, which were later amalgamated to form a group composite SID, providing a comprehensive overview of the factors influencing student engagement.

The second phase of the IQA process involved conducting individual semi-structured interviews with the same five lecturers who participated in the focus group. These interviews, guided by the affinities identified in the focus group, were conducted face-to-face and averaged 56 minutes in length. They were recorded, transcribed, and analysed using the IQA protocol (Northcutt & McCoy, 2004). The semi-structured interviews allowed for a deeper exploration of the affinities generated in the focus group, providing further insights into the factors influencing student engagement. This phase complemented the focus group data by offering a more detailed examination of the participants' perspectives and was integral to the study's mixed-methods approach, enhancing the richness and depth of the data collected.

Ethical considerations were rigorously adhered to throughout the research process. Approvals were obtained from Stellenbosch University (Ethics approval number: 24252) and Nelson Mandela University (Ethics approval number: H22-ENG-CMA-EAP-001). Participation in the focus group and interviews was entirely voluntary, with all participants' informed consent forms duly signed. The adherence to ethical standards ensured the protection of participant rights and the integrity of the research process. The voluntary nature of participation and the requirement for informed consent underscored the study's commitment to ethical research practices. This rigorous attention to ethical considerations reinforces the study's credibility and ensures that the research was conducted with the utmost respect for the participants' autonomy and well-being.

Research Results

Objective 1 identified the factors influencing student engagement among BSc QS Hons students according to QS lecturers. The participants were asked to generate key thoughts (one key thought per sticky note) about the issue statement " *What influences QS student academic engagement at Nelson Mandela University?*" individually and silently. Inductive coding produced thirty-seven key thoughts (sticky notes) taped to a wall. The facilitator read aloud the sticky notes, and the group agreed on the meaning of each card. The facilitator then instructed the participants to silently organise (inductively code) the cards into affinities (Called themes from here on). The grouping was followed by naming and defining the themes (axial coding). The themes and their definitions are shown in Table 1 below.

Table 1: Themes and their definitions as agreed by the focus group

Affinities Names	Definitions of the affinities
Departmental influence	"The department's capacity to affect the character, development, or behaviour of students through the implementation of its protocol."
External factors	"External factors are things outside a student's control that will have an impact on their success."
Group dynamics	"The way in which students in a cohort interact with one another."
Lecturer characteristics	"A feature or quality belonging typically to a lecturer."
Motivation	"The needs, desires, wants or drives within a student."
Personal attributes	"A quality or feature regarded as a characteristic or inherent part of a student."
Skills	"The base knowledge of the student that allows them to engage with the qualification content"

Objective 2 established the relationships between the factors BSc QS Hons lecturers identified. The focus group was asked to analyse the nature of the relationships between each theme after the themes were clearly defined (theoretical coding). They were given specific rules regarding the potential relationships and asked to record their responses on an ART. All the data from the previous individual ARTs were used in the interrelationship diagram (IRD), representing all the themes' relationships. The Pareto Protocol was used to compile the IRD from the focus group. The Pareto Protocol is a statistical method that states that roughly 20% of the variables in a system account for 80% of the variation in the outcome (Northcutt & McCoy, 2004). Table 2 shows the IRD of the focus groups in descending order of delta (Δ).

Table 2: Focus group IRD sorted in descending order of delta (Δ)

	Departmental influence (1)	External factors (2)	Group dynamics (3)	Lecturer characteristics (4)	Motivation (5)	Personal attributes (6)	Skills (7)	OUT	IN	Δ
Departmental influence (1)		↑	↑	↑	↑	↑	↑	6	0	6
Lecturer characteristics (4)	←	↑	↑		↑	↑	↑	5	1	4
External factors (2)	←		↑	←	↑	↑	↑	4	2	2
Personal attributes (6)	←	←	←	←	↑		↑	4	2	2
Group dynamics (3)	←	←		←	↑	↑	↑	3	3	0
Skills (7)	←	←	←	←	↑	←		1	5	-4
Motivation (5)	←	←	←	←		←	←	0	6	-6

The delta value indicates an affinity's relative position within the system. Positive delta affinities are relative drivers or causes, while negative delta affinities are relative effects or outcomes. Pivots occur when the delta value is zero, indicating an equal number of factors influencing the affinity, which in turn influences other affinities. The tentative SID assignments represent the SID's initial affinity placement.

Objectives 1 and 2 assisted in achieving the main aim of the research, which was to develop a group SID for factors influencing BSc QS Hons students' engagement according to QS Lecturers. Figure 1 shows a visual representation of how the lecturer group perceived student engagement during their studies and how they perceived the factors related to one another.

Below is the insight gained into factors that influence student engagement. This paper will discuss only the primary drivers, secondary drivers and pivots since they affect the primary and secondary outcomes identified by the focus group. During the individual interviews, the participants were asked what the departmental influence, external factors, group dynamics, lecturer characteristics, personal attributes, skills and motivation themes mean and how they influence student engagement.

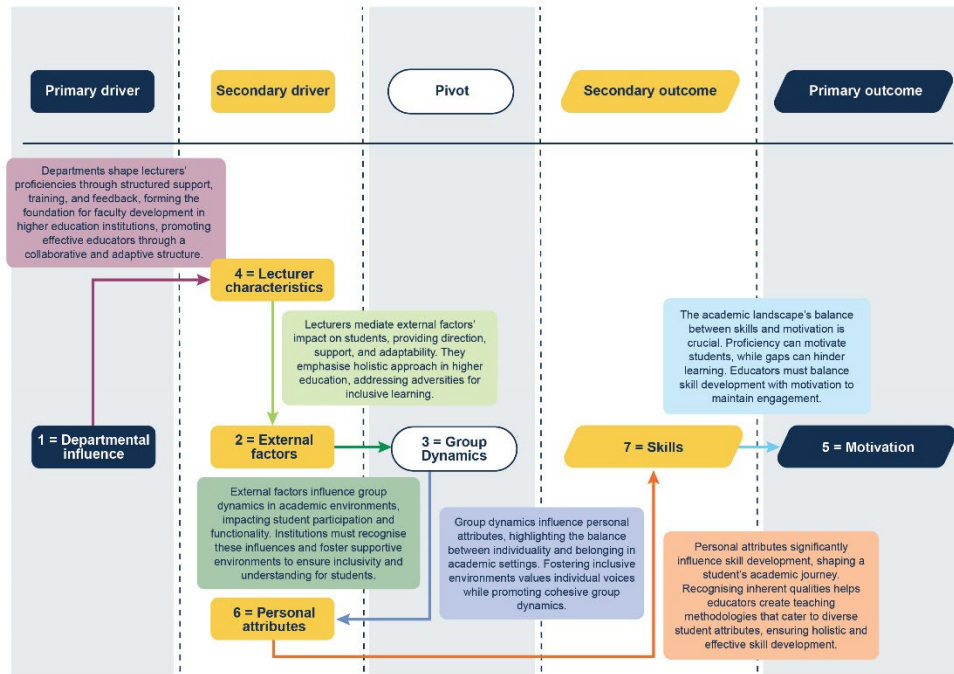


Figure 1: Uncluttered focus group systems influence diagram

Departmental influence

Strong leadership within a department is essential for fostering student engagement, as it establishes the tone and direction of the academic environment. One lecturer emphasised that *"without leadership from the department in promoting engagement, the existing situation will simply persist, whatever that may be."* This suggests that leadership plays a pivotal role in setting expectations and guiding student interactions. Consequently, a department with strong leadership is more likely to cultivate an environment where students are motivated and actively involved.

A cohesive departmental structure significantly enhances clarity and fosters engagement among students. The consistency and disciplined protocols within the department build trust and reduce confusion. As one lecturer noted, *"It's about how everyone operates within a set code of conduct or follows specific disciplinary policies. All these aspects undoubtedly influence student engagement."* This demonstrates that students are more likely to engage meaningfully with their academic work when they are aware of the expectations and feel secure within a structured environment. Therefore, a well-organised department contributes to a stable and supportive learning atmosphere.

Support from the department extends beyond mere academic content, contributing to a sense of security and confidence among students. A lecturer highlighted this by stating, *"It's not strictly about the actual module content, but rather how we, as a department, can assist when a student has a specific need. This, in turn, influences their approach to work."* This indicates that when students feel supported in their broader needs, they are more likely to approach their studies with confidence and commitment. As a result, departmental support systems are crucial in shaping positive student engagement.

The personal connection between the department and students is pivotal in creating a welcoming and accessible atmosphere. One lecturer remarked, *"Students feel safe and welcomed. They believe they can approach us. It's like a haven for them,"* underscoring the importance of fostering open and

supportive relationships. This suggests that when students feel personally connected to the department, they are more inclined to engage actively in their academic pursuits. Thus, fostering strong personal relationships within the department can significantly enhance student engagement.

In summary, the *"Departmental influence"* affinity underscores the importance of leadership, structural consistency, active support, and personal relationships in shaping student engagement. A well-organised and supportive department creates an environment where students feel secure, valued, and motivated to engage fully in their academic pursuits.

Lecturer characteristics

The lecturers' attributes are critical in influencing student engagement in higher education. One lecturer pointed out that *"Lecturers are individuals. They each have their own way of going about things. That's going to come down to personality."* This highlights the significance of a lecturer's personality in shaping their teaching style and interactions with students. When lecturers bring their unique personalities into the classroom, they can create a more engaging and dynamic learning environment, which in turn can enhance student participation and interest.

Approachability and the ability to explain complex concepts are vital for fostering student engagement. A lecturer explained, *"Certainly, the lecturing style and the lecturer's personality play a role in how approachable they seem to students,"* emphasising the importance of making content relatable and engaging. This suggests that when lecturers are approachable and adept at simplifying complex ideas, students are more likely to seek help and participate actively in class discussions. Thus, a lecturer's teaching style and personality are crucial in encouraging student engagement.

Self-awareness among lecturers is essential for understanding their strengths and areas for improvement, which directly impacts student engagement. One lecturer remarked, *"Essentially, it's about understanding who I am as a lecturer. What strengths do I bring to the table? Where do I have areas for improvement?"* This reflection is important because it allows lecturers to adapt their teaching methods to better meet the needs of their students, thereby enhancing the overall learning experience. As a result, self-aware lecturers are better equipped to foster an engaging and supportive classroom environment.

Openness and trustworthiness in lecturers further enhance student engagement, as students are more likely to participate when they trust their lecturer. A lecturer emphasised, *"It's about your approach. Are you open to questions? Do you maintain an open-door policy?"* This indicates that when students perceive their lecturers as open and approachable, they are more likely to engage actively in their studies. Therefore, building trust through openness is key to promoting student engagement.

In summary, lecturer characteristics shape student engagement in higher education. Through their personality traits, teaching approach, self-awareness, and openness, lecturers play a central role in defining the educational experience for their students.

External factors

External factors significantly shape student engagement, particularly through personal, institutional, and societal influences. These factors include life events, technological barriers, socio-economic challenges, institutional policies, and unexpected circumstances that affect student participation in the academic environment.

Life events and personal circumstances can significantly impact student engagement. One lecturer explained, "External factors might include personal events affecting students in the group, like the unfortunate passing of a student. This can foster a negative atmosphere." This highlights how personal tragedies or major life changes can disrupt student interaction and contribute to a disengaged learning environment.

Technological barriers are another crucial external factor. Many students face challenges with computer literacy or lack the operational knowledge to engage with digital tools fully. A lecturer pointed out, *"Numerous students struggled with computer literacy last year. It's not that they lacked the willingness to engage; they didn't know simple tasks, like how to use the virtual hand-raising feature."* This indicates

that a lack of technical proficiency can limit student participation, even when the desire to engage is present.

Logistical challenges, such as geographic constraints or financial difficulties, also hinder effective engagement. Students living in remote areas or lacking reliable internet access face significant barriers to attending on-campus events or engaging in online classes. *"Some students reside in distant areas and lack consistent internet access, which affects their ability to engage,"* explained one lecturer, underscoring the importance of addressing these logistical issues to improve student involvement.

Institutional policies and bureaucratic constraints further complicate student engagement. Decisions made at higher levels within the institution, such as financial aid policies, can affect students' academic experiences. A lecturer noted, *"There are institutional-level factors, like policies from other departments, that we might not have direct influence over."* This suggests that institutional bureaucracy can inadvertently limit student engagement, particularly for those reliant on financial assistance programs.

Socio-economic diversity among students plays a significant role in shaping engagement. Students from varying financial backgrounds often struggle to navigate available resources or funding opportunities, which can impede their academic progress. *"Given the diversity at Nelson Mandela University, students arrive with varied backgrounds,"* explained a lecturer, indicating that socio-economic disparities influence students' ability to engage fully in their studies.

In response to these external factors, institutions and educators need to be flexible and adaptable. By understanding students' challenges, educators can provide the necessary support to help them succeed. One lecturer shared an example, *"A student hadn't engaged in tasks due to external factors. After understanding his situation, I made an exception and allowed him to register late."* This demonstrates the importance of compassion and adaptability in managing external challenges impacting student engagement.

In summary, external factors such as life events, technological barriers, logistical challenges, institutional policies, and socio-economic circumstances profoundly influence student engagement. Addressing these factors requires a flexible, supportive approach from both educators and institutions to foster a more inclusive and engaging learning environment.

Personal attributes

Personal attributes significantly influence self-engagement and group interactions among higher-education students. One lecturer noted, *"It's about the personal attributes of individuals in a group and how these attributes influence others in the same group."* This highlights that individual characteristics can shape the dynamics within a group, potentially fostering a more collaborative and supportive learning environment. When students bring positive personal attributes to a group, it can enhance the overall engagement and productivity of the group as a whole.

Acknowledging the diversity of personalities within the academic environment is essential for fostering student engagement. A lecturer emphasised, *"We must acknowledge the diversity in a classroom... there's the introverted student who might hesitate to ask a question,"* highlighting the need to understand and accommodate different engagement styles. This suggests that recognising and valuing diverse personalities can help create a more inclusive and supportive learning environment where all students feel comfortable participating. Therefore, understanding and accommodating the diversity of personal attributes is crucial for promoting student engagement.

Personal attributes can also determine how well a student resonates with the content or profession. A lecturer observed, *"Some students are drawn to QS because of perceived benefits like potential earnings. However, upon engaging with the content, they may discover that their personality doesn't quite mesh with the profession."* This indicates that a mismatch between personal attributes and the demands of a profession can impact a student's level of engagement. Consequently, educators need to consider how personal attributes align with the course content and professional expectations to enhance student engagement.

Genuine commitment is a clear indicator of positive personal attributes, as engaged students tend to contribute meaningfully to their learning environment. One lecturer noted, *"You can discern which students are truly committed... the genuine commitment and willingness of the students to engage stand*

out." This demonstrates that students are more likely to participate actively and contribute to the learning process when they are genuinely committed. Thus, fostering genuine commitment among students is key to enhancing their engagement.

However, attributing engagement solely to personal attributes can be an oversimplification, as external circumstances also play a significant role. A lecturer explained, *"Much of it pertains to their intrinsic characteristics... but it's also about their current life circumstances,"* highlighting the complexity of understanding personal attributes. This suggests that while personal attributes are important, they must be considered alongside external factors that may influence a student's ability to engage. Therefore, a holistic approach that considers personal and external factors is necessary to foster student engagement.

In summary, personal attributes play a significant role in shaping student engagement, but a combination of intrinsic characteristics and external circumstances influences them. Recognising and addressing this complexity is crucial for fostering a supportive and engaging academic environment.

Group dynamics

Group dynamics significantly impact student engagement in higher education, particularly through collaborative learning and class discussions. Leadership within groups is essential, as it promotes cohesion or creates division. One lecturer noted, *"There are always leaders and followers within any group. Some attributes we discussed can positively or negatively influence group dynamics."* This suggests that the presence of effective leadership within a group can foster a more cohesive and engaged learning environment. Consequently, group leaders play a crucial role in shaping the dynamics and overall engagement of their peers.

Effective group dynamics foster student cohesion and unity, which in turn enhances collaborative engagement and academic performance. A lecturer remarked, *"In such an environment, when one student poses a question, it might reflect the curiosity of several members of the group."* This indicates that when group dynamics are strong, students are more likely to engage collectively in discussions, leading to a richer learning experience. Therefore, fostering strong group dynamics is essential for maximising student engagement and academic success.

A constructive competitive spirit within groups can drive academic excellence, as students motivate each other to excel while maintaining a cooperative approach. One lecturer observed, *"In one year, you might have a group that performs exceptionally, collaboratively challenging one another."* This demonstrates that healthy competition within a group can encourage students to push each other towards higher levels of achievement. As a result, fostering a competitive yet supportive group environment can enhance overall academic performance and engagement.

When group dynamics are strong, students are more likely to engage in a collaborative exchange of ideas and support each other, leading to overall academic success. A lecturer noted, *"They didn't merely 'help' one another, which might hint at academic misconduct; instead, they exchanged ideas and drew support from their peers."* This suggests that strong group dynamics enhance collaboration and promote ethical academic practices. Therefore, cultivating strong group dynamics is crucial for fostering a supportive and academically rigorous learning environment.

The insights from the lecturers underscore the pivotal role that group dynamics play in shaping student engagement. Whether through leadership, cohesion, competitive spirit, or collaborative exchanges, the dynamics within student groups significantly impact their academic experiences and outcomes. By fostering positive group dynamics, educators can enhance both individual and collective student engagement.

Discussion

The findings of this study provide critical insights into the dynamics of student engagement as perceived by QS lecturers at Nelson Mandela University. These insights align with existing literature and expand upon previous research by offering new perspectives that challenge conventional understandings of student engagement within the QS discipline.

Consistent with prior research, this study supports the view that student engagement is a multidimensional construct encompassing cognitive, emotional, and behavioural dimensions (Fredricks *et al.*, 2004; Trowler, 2010). The identification of seven thematic groups—departmental influences, external factors, group dynamics, lecturer characteristics, motivation, personal attributes, and skills—confirms that student engagement is shaped by a combination of internal and external factors (Kahu, 2013). However, this study highlights the particularly influential role of departmental influence as a primary driver of engagement, which has been underemphasised in the broader literature. While previous studies tend to focus on individual or lecturer-driven factors (Krause & Coates, 2008), the findings here suggest that institutional structure and leadership play a more significant role in shaping engagement within QS programs than has been previously acknowledged.

The findings also reinforce the importance of lecturer characteristics in fostering student engagement, echoing the work of Fredricks *et al.* (2004) and Kuh (2009), who emphasise that lecturer-student interactions are crucial for enhancing cognitive and emotional engagement. This is reflected in the lecturers' identification of personality traits and approachability as key influencers. Additionally, the emphasis on personal attributes and skills aligns with existing research linking self-efficacy and intrinsic motivation to higher engagement levels (Reeve, 2012). However, this study adds depth to the concept of group dynamics, offering a more nuanced understanding of the role of leadership within student groups and the balance between collaboration and competition, aspects less frequently discussed as critical factors for engagement.

Moreover, this study challenges established views on external factors and their role in student engagement. While much of the existing literature focuses on internal student characteristics and lecturer-driven influences (Fredricks *et al.*, 2004; Kahu & Nelson, 2018), the present findings indicate that external influences, such as institutional support and personal circumstances, significantly shape student engagement. This suggests the need for further investigation into how external pressures—such as socio-economic challenges and administrative support—interact with personal and academic factors to affect engagement. The identification of departmental influence as a primary driver underscores the potential underestimation of institutional leadership's role in fostering student engagement, particularly within professional degree programs like Quantity Surveying. This opens avenues for future research into how department-level interventions might systematically improve engagement across various academic disciplines.

The findings also raise important methodological considerations. The use of the IQA approach in this study provided deep insights into the system of influences on engagement, particularly by visualising the interrelationships among different factors. This suggests that more interactive and visual methodologies could be beneficial in future studies exploring engagement's complex and interconnected nature. The study highlights the limitations of traditional survey-based approaches, which may fail to capture the full range of engagement factors and their interrelationships, as demonstrated by the qualitative insights gained here.

The results support much of the student engagement literature, including lecturer roles and personal traits. They also emphasise the importance of external influences and departmental leadership in engagement dynamics. This study designed a comprehensive SID to capture the complexity of these influences. These findings should be expanded to examine how institutional structures and external factors promote participation, particularly in discipline-specific situations. According to the study, QS programs and other professional programs may benefit from a more holistic approach that includes lecturer-student relationships and institutional and external assistance.

Conclusion

This study provides important insights into the complex dynamics of student engagement within the Bachelor of Science (Quantity Surveying) Honours program at Nelson Mandela University. By integrating the perspectives of QS lecturers, the research has identified key factors influencing student engagement, including departmental influences, external factors, group dynamics, lecturer characteristics, motivation, personal attributes, and skills. The findings emphasise the pivotal role of departmental influence and institutional leadership as primary drivers of engagement, highlighting a gap in the current literature that tends to focus more heavily on individual student attributes and lecturer-driven factors.

The construction of the SID offers a comprehensive visual framework that captures the intricate relationships between internal and external engagement factors. This approach reveals that external factors—particularly institutional support—play a more substantial role in fostering student engagement than previously recognised. Moreover, the study underscores the importance of group dynamics and the balance between collaboration and competition in shaping engagement within student cohorts.

The study presents a clear message for educators, administrators, and policymakers: improving student engagement requires holistic strategies beyond the classroom. It is essential to address institutional structures and external pressures impacting student experiences. Specifically, targeted interventions at the departmental level can significantly enhance student engagement, particularly within professional programs like Quantity Surveying, where practical and academic demands intersect.

Future research should build upon these findings by further exploring the role of institutional leadership and external support in engagement strategies across various disciplines. This will contribute to more effective, systemic approaches to improving student engagement, retention, and success in higher education. Ultimately, this study suggests that fostering an inclusive, well-supported academic environment is critical for promoting sustained student engagement and academic achievement.

Recommendations

Based on the findings and conclusions of this study, several key recommendations emerge for improving student engagement in higher education, particularly within Quantity Surveying programs. These recommendations aim to guide future research and inform stakeholders, including educators, departmental leaders, and university administrators.

First, it is clear that institutional leadership, especially at the departmental level, plays a critical role in fostering student engagement. As such, universities should place a stronger emphasis on cultivating leadership within academic departments. This can be achieved by providing regular professional development opportunities for department heads and lecturers, equipping them with the necessary skills to create a supportive academic culture. Strong departmental leadership can set the tone for engagement, offering clear guidance and ensuring that institutional policies align with student needs. Departments should adopt strategies that enhance students' academic and emotional well-being, reinforcing engagement through cohesive and supportive structures.

Secondly, a more holistic approach to student engagement is essential. Engagement strategies should not focus solely on the interactions between students and lecturers but should also address external factors that significantly influence student performance. Socio-economic challenges, personal circumstances, and institutional support systems are vital in shaping student engagement. Universities must expand their student services to offer targeted support in these areas, providing accessible academic advising, mental health resources, and flexible learning options to accommodate diverse student needs. This is particularly important in professional programs like Quantity Surveying, where students face practical and academic pressures that can affect their overall engagement.

Furthermore, the importance of group dynamics in student engagement cannot be overstated. Educators are encouraged to implement strategies that promote positive group interactions, such as fostering leadership within student groups and encouraging collaboration while balancing it with healthy competition. Structured peer mentoring programs and collaborative projects can help cultivate these dynamics, ultimately enhancing both individual and collective learning experiences. By focusing on improving group dynamics, educators can create a learning environment that motivates students to engage more deeply with their academic work and peers.

In addition to practical recommendations, this study highlights the need for further research into the external influences on student engagement. Future studies should explore how external factors—such as socio-economic status, institutional policies, and administrative support—interact with internal student attributes to shape engagement across various academic disciplines. Understanding these interactions can provide valuable insights into how universities can better support students holistically and tailor their engagement strategies to meet the specific needs of different student groups.

Finally, the methodology used in this study points to the value of adopting more visual and interactive research approaches. The use of the SID provided a clear representation of the complex relationships

influencing student engagement. Future research in this area would benefit from employing similar methodologies to capture the nuanced dynamics. Researchers can explore engagement patterns more comprehensively by utilising visual tools like SID, offering deeper insights into the factors that drive or hinder student engagement across different educational contexts.

In conclusion, student participation requires strong institutional leadership, comprehensive support systems, and favourable group dynamics. Further research into external elements and interactive methods can help us understand involvement better and improve student results in professional education programs like Quantity Surveying.

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Stressors of Quantity Surveyors in the Eastern Cape

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Abstract

The purpose of this study was to investigate the stressors affecting professional registered quantity surveyors in the Eastern Cape, a group playing a vital role in the construction industry. The construction sector is renowned for its inherent stressors, making it essential to understand what stressors affect quantity surveyors. A qualitative study grounded in the interpretivism philosophy was conducted to achieve the study's objective, employing narrative inquiry as the primary methodology. Through face-to-face meetings with semi-structured interviews, the data collected were thematically analysed to identify key patterns and themes within participants' narratives, using a cross-sectional time horizon to capture insights at a single point in time. The findings indicate that quantity surveyors in the Eastern Cape face a high level of stress due to factors such as inflexible project deadlines, elevated client expectations, and financial pressures. Three overarching themes emerged: Task-related stressors, personal stressors, and practice-related stressors. There was a lack of previous studies on quantity surveyors' stressors. This study is limited in that it only intends to conduct interviews with quantity surveyors from consulting firms. These stressors extend beyond their professional lives, significantly impacting their personal and external well-being. Future longitudinal studies are recommended to understand better how these stressors evolve and their lasting effects on quantity surveyors. Recognising these challenges, industry stakeholders can take steps to support quantity surveyors in managing stress, potentially enhancing their overall well-being and job satisfaction. This research offers valuable insights that can inform strategies for promoting mental health and work-life balance among quantity surveyors, ultimately benefitting both the individuals and the construction industry.

Keywords: Professional Quantity Surveyors, Psychological Well-Being, Stress, Stressors.

Introduction

In the South African economy, the construction industry is pertinent for growth (Herman, 2016). Despite its many challenges, this dynamic sector continues to be marked by rapid urbanisation, infrastructure expansion, and economic vitality (Ebekozi, Aigbavboa, Ngozika, Nwaole, Dako & Awo-Osagie, 2021). However, the construction environment is ever-changing, and quantity surveyors must evolve to respond to existent challenges (Nur Aishah Mohd Noor, Uzairiah Mohd Tobi & Radin Salim, 2020). Professional Quantity Surveyors (PrQS) hold a pivotal role in this field as they are financial consultants for construction projects (Association of South African Quantity Surveyors (ASAQS), 2023). Their expertise guides cost management and navigates the complexities of building projects. Quantity surveyors in South Africa engage in a variety of projects, managing significant workloads and navigating complex contractual and budgeting processes, which play a critical role in the construction industry and contribute to broader economic activities (Bowen, Peihua Zhang & Edwards, 2021). In the Eastern Cape, they engage in a wide array of projects, from residential to commercial to infrastructure development (Nur Aishah Mohd Noor *et al.*, 2020) and previous studies have revealed the industry's demands and the hurdles it presents (James, Rust & Kingma, 2012). Urban centres bring high-pressure deadlines while rural areas present logistical challenges (Verster, 2002). All these roles and responsibilities potentially affect the well-being of quantity surveyors through contributing to distress.

Distress, as related to stress, in the construction industry is a complex component, manifesting in physical strain, environmental uncertainty, acute life events, and chronic stress, as evidenced by nearly half of construction industry workers having taken time off work due to unmanageable stress and mental health issues (Rees-Evans, 2020). Psychological well-being is the paramount, encompassing emotional

health, life satisfaction, self-esteem, and positive functioning (Seligman & Csikszentmihalyi, 2000). It is the art of experiencing joy, forging meaningful relationships, and summoning resilience when adversity knocks (Paul Farmer, & Lord Dennis Stevenson, 2017). The benefits can positively impact physical health, productivity, and overall satisfaction (Keyes, 2007). However, for construction professionals, distress has resulted in isolation, job insecurity, and dwindling job satisfaction (Adedokun, Rufus, Aje & Agboola, 2022).

Yet, investigating the psychological stressors of quantity surveyors remains underexplored. Given the industry's competitive nature and economic impact, this research seeks to determine the specific stressors faced by quantity surveyors in their professional and personal lives. Through this endeavour, the study aims to unearth insights that will empower quantity surveyors to effectively manage their stress, thereby enhancing their well-being and contributing to heightened productivity (Adedokun *et al.*, 2022).

The following section provided a comprehensive exploration of stress, encompassing its concept and various types. This investigation delved into existing literature regarding stressors that impact quantity surveyors. After the methodology was explained, this research conducted a thorough analysis of the demographic profiles of the study's participants and examined the stressors that influenced both their personal lives and professional obligations. As a conclusion of these in-depth inquiries, the study furnished recommendations tailored to the needs of quantity surveyors while also illuminating potential avenues for future research within this field.

Literature Review

The concept of stress

Stress can be defined as a physiological and psychological response to external pressures or demands that exceed an individual's perceived ability to cope effectively (Selye, 1976). Stress is not just a response to external factors but involves the individual's cognitive appraisal of those factors (Lazarus & Folkman, 1984). According to Lazarus' Cognitive Appraisal Theory, stress arises when an individual perceives a discrepancy between the demands placed on them and their ability to meet those demands. This appraisal process highlights the subjective nature of stress, which varies from person to person factors (Lazarus & Folkman, 1984). Stress activates the body's stress response system, which includes hormonal and neurological changes (Selye, 1976). Stress can arise from various sources, such as work-related challenges, personal life events, and environmental factors, and it can have a significant impact on an individual's well-being, both mentally and physically (Yaribeygi *et al.*, 2017).

Types of stress

Stress can be triggered by various stimuli known as stressors. These stressors can be classified into two main categories: physiological or physical stress factors and psychological stress factors ("Stressors ", 2019). Mental Health Foundation, (2021) has identified and defined common types of stressors experienced by individuals. Work stressors encompass excessive high-pressure work environments, while financial stressors involve issues related to individuals' expenditures, excessive debt, and living pay-check to pay-check. Emotional stressors include relationship troubles and a lack of social support within the community.

Stress can be categorised into three main types: acute, chronic, and episodic Mental Health Foundation, (2021).

- **Acute Stress:** This is a short-term response to an immediate threat or challenge, such as a tight project deadline for quantity surveyors. While acute stress can be intense, it is typically short-lived.
- **Chronic Stress:** This type of stress develops over an extended period and can result from persistent job-related challenges, like ongoing job insecurity or prolonged exposure to a high-pressure work environment.
- **Episodic Stress:** This occurs when an individual frequently experiences episodes of acute stress. For example, a quantity surveyor who repeatedly encounters high-pressure situations may develop a pattern of episodic stress, which can lead to a continuous state of heightened arousal.

Stressors and their classification

Stressors are the stimuli or demands that trigger the stress response. They can be classified into various categories, reflecting different perspectives on how stressors influence an individual's well-being. In the context of occupational stress, researchers often distinguish between task-related stressors and organisational-related stressors (Karasek, 1979). Karasek's Job Demand-Control (JDC) Model emphasises the interaction between job demands and the level of control an individual has over their work environment. According to this model, high job demands coupled with low control can lead to increased stress levels.

Stressors that affect quantity surveyors' psychological well-being

The South African Council for the Quantity Surveying Profession (2020) defines a Professional Quantity Surveyor (PrQS) as an individual officially registered under the Quantity Surveying Profession Act, 2000 (Act No. 49 of 2000). They offer specialised, expert guidance and services in the fields of construction procurement, contracting, and cost management. Quantity surveyors provide advice, work collaboratively, and foster cooperation with fellow professionals in the built environment sector as well as construction industry stakeholders.

In a comprehensive study conducted by Adedokun et al. (2022), the researcher examined the stressors experienced by quantity surveyors, with a focus on distinguishing between consulting and contracting positions. The study unveiled distinct stressors encountered by these professionals based on their roles. Consulting quantity surveyors reported primary stressors related to organisational, environmental, and personal factors. While contracting quantity surveyors faced a separate set of stressors, which encompassed job insecurity, early life experiences, role expectations, immune system irregularities, interpersonal interaction needs, and personality factors.

To effectively address these stressors, Adedokun (2022), recommended the implementation of targeted stress management programs tailored to the specific triggers identified. The ultimate goal is to cultivate a work environment that is conducive to reduced stress levels and enhanced well-being for quantity surveyors.

Additionally, Leung, Liang & Chan (2017) highlighted several stressors specific to contracting quantity surveyors. These stressors include:

- Heavy workloads and inflexible schedules,
- Shortcomings in the tender process such as under-priced quotations and document discrepancies,
- Poor information flow leading to delays in approval of variations and issuing of drawings,
- Inadequate attention to site safety,
- Workplace discrimination,
- Comparisons of qualifications with peers in other contractors,
- Unplanned and frequent changes to meet employers' requirements,
- Lack of employee motivation, well-being, and performance evaluation,
- Pressure from superiors, and the use of obsolete technologies at construction sites.

Leung, Liang & Chan (2017) highlights the importance of identifying stressors as a means of effectively managing and coping with stress, particularly considering the gender-based differences in the causes of stressors. Their research specifically focuses on contracting quantity surveyors, revealing that these professionals face significant workloads and demanding tasks due to the limited project timeframe. This often requires them to put in extra time and effort to meet strict project deadlines.

While research has been conducted on identifying stressors in the contracting industry, there is a gap in research that specifically focuses on consulting quantity surveyors.

Task-related stressors

Ajayi, Jones & Unuigbo (2019) underscored two critical stressors highly ranked among construction professionals: the reliance on others to complete preceding tasks and the dependence on others to

provide crucial information. Task-related stressors are intrinsically linked to the inherent nature of the job, particularly the intricate complexities and demands associated with cost estimation responsibilities. Cost estimators routinely navigate intricate and time-pressured projects demanding meticulous attention to detail, analytical prowess, and sound decision-making (Leung M *et al.* 2017).

The relentless pressure to meet stringent deadlines, manage substantial data volumes, and adapt to swiftly shifting project requisites contributes to stressors stemming from the tasks themselves (Adedokun *et al.* 2022). Mitigating task-related stress necessitates the provision of comprehensive training, unhindered access to resources, and a supportive managerial framework (Ojo, Adeyeye, Olawale & Kajimo-Shakantu, 2019).

Furthermore, the integration of streamlined processes and advanced tools can not only enhance precision but also streamline the estimation workflow, effectively reducing the workload placed on estimators, (Adedokun *et al.* 2022). Ojo *et al.* (2019) highlighted a range of stressors, including excessive paperwork, inadequate workload, pressing deadlines, extensive working hours, limited involvement in decision-making, performance pressure, the need to outperform peers, ambitious timeframes, skill inadequacy, travel-related commutes, and isolation during work.

Interpersonal stressors

Interpersonal stressors manifest from the dynamics between individuals in the workplace and external stakeholders. In the realm of cost estimation, professionals often find themselves interacting with project managers, clients, team members, and other stakeholders (Leung M *et al.* 2017). The intricacies of these interactions can potentially introduce communication hurdles, conflicts, and disputes, leading to stress and influencing job effectiveness (van Eck & Burger, 2018). Furthermore, the task of managing expectations, navigating critical feedback, and reconciling conflicting demands can emerge as noteworthy sources of interpersonal stress for estimators (Ojo *et al.* 2019).

Research by Adedokun *et al.* (2022) and Leung, Liang & Chan (2017) underscores the impact of interpersonal stressors on professionals in the construction industry, particularly quantity surveyors. Adedokun *et al.* (2022) identified that factors like role expectations, interactions with colleagues, and challenges in collaboration contribute to the stress experienced by consulting quantity surveyors. The study that task demands, office politics, policies and regulations were the highest triggers among quantity surveyors. Similarly, Leung, Liang & Chan (2017) highlighted the strain brought about by issues like poor communication, discrimination, and peer comparisons among contracting quantity surveyors.

Organisational-related stressors

Organisational-Related stressors encompass a spectrum of challenges that professionals within the built environment contend with. These stressors can have far-reaching impacts on their psychological well-being. As highlighted by Ojo *et al.* (2019), a host of stress-inducing factors emerge from the organisational dynamics. These include but are not limited to issues such as inadequate staffing levels, poor communication channels, deficient planning, a lack of comprehensive on-the-job training, absence of constructive feedback mechanisms, interpersonal conflicts, strained relationships with superiors, instances of bullying and harassment, and instances of discriminatory behaviour. Moreover, factors such as inadequate compensation, unfavourable work status, role ambiguity, conflicting role expectations, variations in job scope, and insufficient managerial support compound the organisational stressors.

The lack of defined career progression, uncertainties regarding job security, limited opportunities for job promotion, and the ability to secure comparable job positions expeditiously further contribute to the psychological strain experienced by professionals within this sector. Adedokun *et al.* (2022) study in Nigeria unearthed five stress triggers among quantity surveyors, with task demands and office policies being the prominent stress triggers in organisational stressors. In a 2014 study conducted by Cumberlege & Claasen in South Africa, it was determined that the practice of reducing quantity surveying fees had adverse consequences.

The research revealed that such reductions led to a decline in the quality of services provided by quantity surveyors. Consequently, quantity surveyors often found themselves involved in projects where they could not expect to make a profit due to the reduced fees (Snyman & Cruywagen, 2005). This situation placed significant stress on these professionals, as they were essentially overextending

themselves without the promise of satisfaction or financial rewards, thereby impacting their well-being both within their organisations and in their personal lives.

Research Methodology and Method

A qualitative research design was employed to explore the complex experiences and mental states of quantity surveyors, a subject not easily quantifiable (Saunders *et al.*, 2019). Given the subjective and nuanced nature of this topic, semi-structured interviews were selected to facilitate a deeper understanding of participants' perspectives.

The data collection instrument was designed based on a thorough review of the literature on stressors affecting quantity surveyors. This literature review helped identify key themes and informed the development of the interview questions. The semi-structured interview guide included open-ended questions aimed at eliciting detailed responses. To ensure the instrument's validity, the questions were reviewed and refined by academic supervisors. Their feedback helped ensure that the questions were clear, relevant, and capable of capturing the intended data.

Purposive sampling was used to select a diverse sample of both male and female registered professional quantity surveyors practicing in the Eastern Cape region. This approach aimed to gather rich, relevant data to address the research questions rather than seeking statistical generalisation ((Saunders *et al.*, 2019). The sample was drawn from the forty (40) active professionally registered quantity surveying firms in the area (ASAQS, 2023).

The primary data collection method was semi-structured interviews. This method allowed for flexibility in exploring emerging topics while maintaining a focused discussion on the key research areas. The use of open-ended questions facilitated an in-depth exploration of participants' experiences (Saunders *et al.*, 2019). Interviews were recorded and transcribed for analysis.

To enhance the study's reliability and validity, the interview guide was designed to include questions that allowed for triangulation through cross-verification of responses. The researcher employed clarifying questions during interviews to ensure an accurate understanding of participants' responses. Additionally, feedback from supervisors and experts helped refine the data collection process, thereby enhancing validity.

Recorded interviews were transcribed, and the transcripts were systematically coded using Atlas.ti software. An iterative coding process was employed, allowing for the identification of themes and patterns within the data. To ensure rigor in the analysis, the researcher maintained an audit trail documenting key decisions and coding procedures (Aguinis & Solarino, 2019). The use of Atlas.ti facilitated a systematic approach to coding and analysis, contributing to the reliability of the findings.

Ethical considerations were paramount throughout the study. Informed consent was obtained from all participants, and measures were taken to ensure confidentiality and participant protection. The study received approval from the Mandela Ethics Online System (MEOS), with both the researcher and supervisor completing the necessary ethics training modules (0151).

Research Results

Profile of respondents

In the first phase, personalised emails were sent to eligible respondents based on predefined criteria. Professional quantity surveyors then proactively contacted the researcher to coordinate interview schedules. Out of thirty (30) initial emails, only four respondents confirmed interviews at their preferred dates. The remaining two were personally contacted and willingly agreed to participate, choosing interview dates. The study focused on registered professional quantity surveyors in the Eastern Cape, South Africa, with a population of forty (40) firms. Six respondents from this region participated. Data collection continued until saturation, identified through recurring themes and patterns in responses, indicating a comprehensive understanding of the targeted group.

Table 1: Profile of respondents

	R1	R2	R3	R4	R5	R6
Gender	Male	Female	Male	Male	Male	Male
Types of Projects	Private Sector	Private Sector	Private Sector	Public Sector	Private & Public Sector	Public Sector
Working Hours	08:00 AM - 17:00 PM	08:00 AM - 17:30 PM	08:00 AM - 17:30 PM	08:00 AM - 17:00 PM	08:00 AM - 17:30 PM	08:00 AM - 17:00 PM
Business Size	Medium-Sized Firm	Medium-Sized Firm	Small-Sized Firm	Medium-Sized Firm	Small-Sized Firm	Small-Sized Firm
Location	Gqeberha, Eastern Cape	Gqeberha, Eastern Cape	Gqeberha, Eastern Cape	East London, Eastern Cape	East London, Eastern Cape	East London, Eastern Cape
Position in Company	Director	Professional Quantity Surveyor	Professional Quantity Surveyor	Professional Quantity Surveyor	Professional Quantity Surveyor	Professional Quantity Surveyor

Stressors that affect the psychological well-being of quantity surveyors

The study identified three distinct themes that surfaced regarding the stressors that influence the psychological well-being of quantity surveyors: *Task-Related stressors*, *Personal stressors*, and *Practice-Related stressors*.

R1 provided a comprehensive definition of psychological well-being, describing “*your general mental state and probably a little bit more of a softer answer would be your well-being and your happiness and stability in terms of mentally where you are*”. The study identified one prominent theme regarding the stressors that influence the psychological well-being of quantity surveyors: *Task-Related Stressors*. The respondents demonstrated a comprehensive grasp of the concept of psychological well-being, encompassing one’s state of mind and overall day-to-day mental disposition (Seligman & Csikszentmihalyi, 2000). They explored the intricate relationship between stress and its impact on one’s well-being. R3 reported that “*stress is part of the job*”, emphasising that the role often offers limited job satisfaction beyond survival and employment continuity (Bowen *et al.*, 2021). R3 also highlighted that client satisfaction can serve as a source of job satisfaction in this context.

Theme 1 – Task-related stressors

Respondents illuminated several critical themes that underscore the impact of various stressors on the psychological well-being of quantity surveying professionals. These stressors were voiced by the respondents and encapsulated a spectrum of factors, all of which intricately affected their daily work experiences and overall equilibrium.

Workload, extended hours, and project deadlines:

One of the recurring stressors that respondents highlighted was the demanding workload and the requirement for extended work hours, often spilling into overtime (Ojo *et al.*, 2019). R3 vividly captured this struggle, explaining, “*Capacity drops from the stress, and you can see it in your work in terms of what you can do in a day.*” This incessant workload was exacerbated by the weight of managing someone else’s budgets, as described by R1: “*Pressure that gets placed on you to manage somebody else’s budgets.*”

Project-related stress emerged as a significant theme, particularly in the context of meeting deadlines and managing financial concerns (Leung M *et al.*, 2017). Juggling multiple projects, each with distinct expectations and demands from various directors was described as a significant source of stress (Ajayi *et al.*, 2019). R1 added to this sentiment, stating, “*The private sector is incredibly stressful because every single decision you make impacts on somebody, and they are very sensitive about how their money gets spent.*”

Financial stress and unrealistic expectations:

This theme revolved around the financial stress associated with adhering to project budgets, especially when clients had invested their life savings and placed their trust in promises of success (Adedokun, 2022). The respondents also emphasised the variability in project requirements and the imposition of unrealistic timeframes, which contributed to their stress (Adedokun *et al.*, 2022). These challenges necessitated re-evaluation and often resulted in the imposition of time constraints (Leung M *et al.*, 2017). As expressed by R4, *"Eats into my life outside"*.

One significant theme revolves around task-related stressors, which are an intrinsic part of the quantity surveying profession (Adedokun *et al.*, 2022). Quantity surveyors face demanding workloads and often find themselves working extended hours, occasionally spilling into overtime (Ojo *et al.*, 2019). These pressures are intensified by the weight of managing someone else's budget, leading to diminished capacity and potential work quality issues. Project-related stress is another key component, with the constant challenge of meeting project deadlines while handling financial concerns, particularly in the private sector (Gunasekara & Perera, 2022). The complexity of juggling multiple projects, each with distinct expectations and various directives, significantly contributes to the stress that these professionals experience (Van Eck & Hoffman, 2022). Additionally, managing project budgets and dealing with clients' high expectations pose financial stress and create constraints that intrude into personal lives (Ojo *et al.*, 2019).

Theme 2 – Personal stressors

In theme 2, a comprehensive exploration into the personal stressors shared by the respondents unravelled the intricate relationship between their individual experiences and their professional roles.

Client relations as a source of stress:

One prominent theme that emerged was the complex world of client relations. The respondents expressed the constant challenge of meeting clients' expectations while often feeling undervalued. They spoke of the perpetual pressure and the sense of being always on call, which took an emotional toll. R3 provided insight into the restless nights that often accompany these demands, saying, *"You wake up during the night and you flip and roll around and you're thinking that 'Did I do this? Did you include something that is not included?'"* As articulated by R3, *"They feel like they own you,"* highlighting the pressure of dealing with client's high expectations.

Senior team members: Elevated expectations and responsibilities:

Senior team members faced unique stressors, primarily stemming from elevated expectations and increased responsibilities. These included overseeing complex projects and mentoring junior quantity surveyors while dealing with heightened scrutiny. R6 highlighted the impact of accumulating experience on personal life, explaining, *"The more experience you become, the more it affects your home life, the more you are expected to work after hours, whether it's a phone call or whether it's information."*

Diverse responses to stress:

A key realisation among the respondents was that stress manifests differently in individuals. While some thrive under pressure, others struggle to maintain effective performance. This understanding of diverse responses is crucial for effectively addressing stress within the profession, recognising its unique personal dimensions. R4 emphasised how stress impacted family life, stating, *"It's a stress that I would not have put on my family."*

Changing perceptions of mental health:

The respondents also noted the shifting perception of mental health, especially in the post-COVID-19 landscape. R2 highlighted this evolution, saying, *"Nowadays people are more aware of mental health, and they are more willing to speak out about it, especially since COVID-19 somehow changed everybody's perception."*

Dealing with mistakes and criticism:

Dealing with mistakes and criticism was another personal stressor raised by the respondents. R1 articulated the anxiety surrounding criticism, stating, *“Getting any sort of criticism is an incredibly stressful item.”*

Balancing personal and professional triggers:

The challenge of balancing personal and professional triggers was particularly burdensome. R4 illustrated this struggle, noting, *“As much as you are here at the office, you still have triggers from home.”*

These personal stressors, as voiced by the respondents, offer a multifaceted view of the challenges faced by quantity surveying professionals in their pursuit of well-being, both professionally and personally. Recognising these nuances and personal dimensions is crucial for addressing and mitigating stress within the profession.

The personal stressor's theme dives into the intricate relationship between quantity surveyors' individual experiences and their professional roles. The complex world of client relations often places individuals under constant pressure to meet client's expectations while often feeling undervalued (Panojan, Perera & Dilakshan, 2022). This leads to emotional strain and restlessness. Senior team members face elevated expectations and responsibilities, which include overseeing complex projects and mentoring junior quantity surveyors, with a heightened level of scrutiny. Moreover, the understanding that stress manifests differently in individuals is a key realisation, with some thriving under pressure and others struggling to maintain effective performance. This theme also highlights the shifting perception of mental health, particularly in the post-COVID-19 landscape (van Eck & Burger, 2018). Coping with mistakes and criticism and the challenge of balancing personal and professional triggers further add to the personal stressors that quantity surveyors grapple with (Bowen, Cattell & Edwards, 2014).

Theme 3 – Practice-related stressors

Within theme 3, the external factors that exert practice-related stressors on professionals in this field, stemming from industry dynamics and economic considerations are explored. Firstly, the issue of discounted fees emerged as a significant source of stress.

Discounted fees as a source of stress:

One significant stressor that respondents emphasised was the issue of discounted fees. Engaging in tender processes with slim profit margins and outdated fee structures was cited as a financial strain. The additional challenge of staying competitive in a market where fee adjustments have been stagnant for years compounds this stress (Snyman & Cruywagen, 2005). R4 underscored the challenge of discounted fees, stating, *“Discount these days, and you're taking on much more work than you would have taken on in the past.”*

Competition within the industry:

The competitive landscape within the industry represents another substantial stressor. Quantity surveying professionals are faced with the ongoing imperative to secure projects and contracts while navigating the delicate balance between winning bids and maintaining profitability (Snyman & Cruywagen, 2005). R5 highlighted the stress associated with meeting industry standards and adapting to industry changes, saying, *“The biggest single stress issue is trying to achieve the standards and to do the job the way you always used to do it.”* Additionally, R4 echoed the sentiment regarding the stress linked to offering discounts, emphasising, *“We should not be giving discounts that will improve our lives a little bit.”*

The interplay between these external factors and the well-being of quantity surveying professionals underscores the complex challenges inherent to this industry. Financial strain was a prevalent concern, as articulated by R5, who mentioned, *“The stress comes with trying to do the work without having the financial backup to do it.”* Furthermore, both R4 and R5 recognised the added stress induced by subpar workmanship from other disciplines within the construction industry, particularly architects and engineers (Ojo *et al.*, 2019).

These external stressors, as revealed by the respondents, shed light on the intricate web of challenges faced by quantity surveying professionals, stemming from industry dynamics and economic considerations. Understanding and addressing these factors are paramount for sustaining well-being in this profession.

The third theme explores external stressors influenced by industry dynamics and economic considerations. One significant source of practice-related stress is discounted fees. Engaging in tender processes with slim profit margins and outdated fee structures places quantity surveyors under significant financial strain (Ojo *et al.*, 2019). The additional challenge of staying competitive in a market where fee adjustments have stagnated for several years compounds this stress. Furthermore, the competitive landscape within the industry represents another substantial stressor. Quantity surveying professionals must continuously secure projects and contracts while carefully balancing the need to win bids and maintain profitability (Snyman & Cruywagen, 2005). Meeting industry standards and adapting to industry changes add to the challenges. The practice of offering discounts in an attempt to secure projects can further exacerbate this stress, with some individuals expressing concerns about the negative impact on their personal lives.

Conclusion

This study sought to shed light on the intricate challenges related to the psychological stressors experienced by quantity surveyors in the Eastern Cape of South Africa. Given the demanding and stress-laden nature of their work environments, a meticulous examination of the psychological well-being of these professionals becomes essential. The study has demonstrated that South African quantity surveyors contend with elevated levels of stress. This not only endangers the individual well-being of these professionals but also poses a substantial threat to the sustained economic growth of the construction industry, as indicated in previous research.

Regrettably, the body of research focusing on quantity surveyors in the South African construction industry remains notably limited. The concern for the psychological well-being of quantity surveyors has been exacerbated by the recent and ongoing impacts of the COVID-19 pandemic, further emphasising the urgency of conducting a comprehensive investigation. Given these pressing issues, delving into the stress factors affecting quantity surveyors becomes a crucial step toward improving stress management strategies and, ultimately, enhancing productivity.

The study identified three primary stressors among quantity surveyors in the Eastern Cape: *Task-Related Stressors*, *Personal Stressors*, and *Practice-Related Stressors*. These findings provide a comprehensive understanding of the stressors affecting these professionals and lay the groundwork for developing effective interventions and strategies to mitigate the negative impact of stress on quantity surveyors.

Recommendations

To quantity surveyors

Creating awareness among the young quantity surveyors to the stressful nature of their profession.

Develop proactive measures to identify and manage various stressors, such as design changes and variations in final accounts, through improved communication, project planning, and change management processes.

To quantity surveying firms

Encourage organisations to adopt family-oriented practices, such as open-door policies, informal gatherings, and team-bonding exercises, to cultivate a more positive and friendly work environment for quantity surveyors.

Foster a culture of resilience and stress management by offering resources and workshops that empower quantity surveyors to cope with various stressors and develop self-confidence.

To higher education institutions

Develop industry-wide guidelines to address discounted fee structures, by advocating for fair compensation practices and transparent fee negotiations.

Provide platforms for quantity surveyors to share experiences and insights, including financial strain and self-doubt, and offer financial planning support and stress management resources.

Areas of further research

Longitudinal Studies: To gain a deeper understanding of the long-term effects of various stressors on quantity surveying professionals, longitudinal studies should be conducted. This study can help track how stressors evolve and impact well-being over time.

Comparative Studies: Conduct research to compare the impact of stressors on different members of the project delivery team, including architects, project managers, construction managers, and health and safety practitioners. Such studies could provide a broader understanding of how stressors affect various roles within the project delivery process and highlight potential areas for targeted support and intervention.

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Technology-Organisational-Environment Considerations in Implementing Drone Technology on Construction Sites: A Case of the South African Construction Industry

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Abstract

In recent years, unmanned aerial vehicles (UAVs) have had a tremendous impact on the global construction industry as surveying, inspections and monitoring tools due to their immense technological capabilities. However, certain attributes, practices, and characteristics influence the adoption of these tools. Hence, this study is purposed to provide an in-depth exploration and contextual interpretations of the technological, organisational, and environmental contexts that influence the adoption and implementation of drone technology in construction project management. This study combines a systematic literature review and a contextual inquiry using the TOE framework as a theoretical underpinning. The review of the literature followed an analysis of 37 peer-reviewed articles. The inquiry involved in-depth observation and semi-structured interviews with drone operators and construction project coordinators on three construction sites during the deployment of drone technology. The findings reveal that South Africa shows growth in commercial drone usage, but regulatory challenges, organisational policies, resource allocation, resistance, and site complexities hinder deployment in construction. While technological advancements offer potential, limitations such as connectivity, battery life, and software compatibility remain obstacles. This study is limited to the qualitative assessment of the factors that influence the adoption and implementation of drone technology from a small number of cases. However, rich data was obtained, which is reliable and can be cross-validated. The study provides insights into crucial elements in assessing the practicality of drone-enabled on-site processes. This can assist key industry players as a benchmark when exploring the value of drone-aided processes prior to establishing a drone program within their organisation. This paper is underpinned by relativist ontology and focuses on complex, rich contextual interpretations of drone adoption challenges occurring within the context of the South African construction industry.

Keywords: Unmanned Aerial Vehicles, Drone Technology, Construction Industry, Adoption.

Introduction

The rise of digitisation, robotics, and automation technologies during the 4th industrial revolution has brought significant changes to the global construction industry, transforming project planning, design and execution methodologies. Notably, the application of drone technology, a key component of this transformation, has increased by over 50% since the onset of COVID-19 and is poised to grow at an annual compounded growth rate (CGR) of approximately 18%. Consequently, the global construction drone market is projected to surpass 10 billion by 2030 (Edulakanti and Ganguly, 2023; Nwaogu *et al.*, 2023; Skyquest, 2023). Nevertheless, the deployment of drones in construction site management can be described as a relatively new phenomenon, and industry players are currently learning about their potential uses in this regard (Kim and Irizarry, 2020). However, the utilisation of drones is projected to have a significant impact in the construction industry.

Particularly, the construction industry has significantly benefited in aspects such as surveying, inspections and project progress monitoring. Due to their versatility, data processing and analytics capabilities, drones have emerged as invaluable tools, facilitating a shift from traditional quality control

practices to more proactive and comprehensive quality assurance approaches (Hammad *et al.*, 2021). This transition enhances efficiency and brings about a future-focused paradigm shift in construction project management. For example, Morgenthal *et al.*, (2019) are of the opinion that as drone technology evolves, the synergy between drone advancements and quality assurance practices will likely define the next era of quality management systems across the construction industry.

As noted by Choi *et al.*, (2023), robotic and automation technologies like drones give businesses in the built environment cutting edge possibilities by offering remote monitoring, actuation, and predictive capabilities, thus enhancing operational intelligence. According to Falorca, Miraldes and Lanzinha, (2021), drones are at the heart of gathering intelligent and actionable data in real time while eliminating risk of incidents and injuries. Thus, mitigating the exposure of site personnel to hazardous elements and unfavourable conditions. Moreover, issues such as manual data collection and communication which is inefficient and time consuming (Mohamed and Tran, 2022). Additionally, conventional inspection and monitoring processes tend to be subjective, with the accuracy of findings relying on the skills and experience of the inspection personnel. Likewise, a significant constraint in current approaches is the limited accessibility of infrastructure systems where considerable expense is necessary for obtaining visual access to critical system components (Choi *et al.*, 2023; Albeaino and Gheisari, 2021).

While studies such as Mokoena *et al.*, (2023) investigated the technological growth of the South African drone industry, their study only focused on commercial drone operators and service providers without paying attention to construction related functions. On the other hand, Jensen, Uys and Cook, (2022) mainly focused on reporting the feasible symbiotic relationship between drone technology and the construction industry in exploring the use of drone technology within the South African built environment without adequate consideration of specific internal and external factors in drone adoption. Therefore, this paper departs from previous studies by providing an in-depth analysis of the internal and external factors, including the characteristics of drones and the context in which these tools are utilised, which influence the adoption and implementation of drone technology in construction project management. The key factors identified are contextualised using the Technology-Organisation-Environment (TOE) framework which considers both sides of the adoption equation. The objectives of this paper are as follows:

- To identify the attributes of drones that affect their adoption in construction project management.
- To examine the contextual factors that influence drone technology implementation in construction projects

Literature Review

General considerations about drone technology potential for the construction industry

The use of drones in construction project management can encompass a range of functions, including real-time project progress monitoring of construction activities and conducting aerial photographic mapping and surveillance using LiDAR technology (Guan, Zhu and Wang, 2022; Martinez *et al.*, 2021). However, Sawant, (2021) and Falorca and Lanzinha, (2020) highlight the capability of drones to perform visual inspections in difficult-to-access areas while capturing detailed images and generating accurate high-quality 3D maps. This equates to improved safety, swift identification of nonconformances, and a live comparison between as planned and actual timelines (Rey, de Melo and Costa, 2021; Zhou and Gheisari, 2018). Generally, a comprehensive view of drone technology potential in construction is provided in extant literature. While Zhou and Gheisari (2018) offer foundational insights into operational uses, Sawant *et al.* (2021) and Falorca and Lanzinha (2020) advance the discussion with a focus on data quality and surveying efficiency. On the other hand, authors such as Rey *et al.* (2021) and Martinez *et al.* (2021) contribute a critical perspective on real-time monitoring and decision-making.

Enablers and drivers of drone technology proliferation in construction

Understanding the diffusion of drone technology within the construction industry requires the appreciation of the interests of key role players in adopting the technology and the capacity within the industry to absorb and develop the technology (Kim and Irizarry, 2020; Guo and Wang, 2022). Similarly, one must focus on the strategic value of drones for key role players and discuss how the current status quo of the construction industry could be an incentive in the implementation of the technology. Second to that, attention must be paid to the supply side of drones within the country, focusing on how

technological evolution may stimulate progress in the development of drone technology. Although competition is often a major driver in technology adoption, willingness also depends in part on the organisational factors such as financial capacity (Steiber *et al.*, 2020). Generally, in the construction industry, certain factors play a crucial role in the widespread use and integration of technologies such as commercial drones. Table 1 below illustrates three main factors extrapolated from extent literature that are seen as encapsulating enablers in driving proliferation of drone technology adoption within the construction industry.

Table 1: Enablers in driving proliferation of drone technology adoption

Enablers	Driving factors	Sources
Regulations which facilitate and promote drone economy	Well-defined regulations with clear guidelines ensuring safety and efficiency in operations	Duque, Seo, & Wacker (2018); Henderson (2022); Mokoena <i>et al.</i> (2022); Yıldız <i>et al.</i> (2021)
Technological evolution	Rapid advancements in hardware and software solutions that	Ruiz <i>et al.</i> (2021); Bayomi & Fernandez (2023); Ameli <i>et al.</i> (2022); Choi <i>et al.</i> (2023); Macrina <i>et al.</i> (2020)
Operational efficiency, enhanced data quality and accessibility	Synergy of operational efficiency, improved data quality, and increased accessibility	Asadi <i>et al.</i> (2020); Nwaogu <i>et al.</i> (2023); Yi & Sutrisna (2021)

The regulatory landscape for commercial drone operations stands as a pivotal determinant influencing the rate at which key role players adopt drone technology (Duque, Seo and Wacker, 2018; Henderson, 2022; Mokoena *et al.*, 2022). Extant literature reveals that professionals acknowledge the benefits of drone utilisation but seek well-defined regulations governing when and where drones can be used. Moreover, there is a need for guidelines ensuring the safety and efficiency of drone operations and clarity on the criteria authorities use for issuing licenses or permits for commercial drone applications (Mokoena *et al.*, 2022). To address these concerns, the development of regulatory frameworks with the aim to establish guidelines that facilitate the secure and business-friendly use of drones, which will in turn catalyse the acceptance of drone-aided functions within the construction industry is a necessity to drive proliferation (Yıldız *et al.*, 2021).

In examining the technological evolution of drones, several studies present varied perspectives that reveal both complementary insights and conflicting conclusions. For instance, Ruiz *et al.*, (2021) and Bayomi & Fernandez (2023) emphasise the role of decreasing costs and hardware advancements in expanding drone applications, noting that these factors are critical for stimulating investment. However, while both studies agree on the importance of technological evolution, they differ in their assessments of how rapidly these changes are driving proliferation. Ruiz *et al.*, (2021) adopt a more optimistic outlook, suggesting a near-term acceleration in adoption, whereas Bayomi & Fernandez (2023) caution that existing regulatory frameworks may still pose significant barriers.

On the other hand, Choi *et al.*, (2023) introduce the concept of hydrogen fuel cells as a pivotal advancement, arguing that these could revolutionise drone efficiency. This perspective contrasts with the more traditional focus on electric batteries highlighted by Macrina *et al.*, (2020) and York *et al.*, (2020) who focus on advancements in lithium battery technology and wireless power transfer. This divergence suggests a gap in consensus on the most promising technological pathway, indicating that significant infrastructure and market adoption challenges remain. Furthermore, Freimuth & König (2018) highlight the development of autonomous collision avoidance systems as a crucial advancement, which is a critical factor for wider acceptance in industries like construction. This study provides differing views to the concerns raised by Asadi *et al.*, (2020) and Nwaogu *et al.*, (2023), who accentuate operational efficiency and data quality. In essence, the synergy of operational efficiency, improved data quality, and increased accessibility positions drone technology as a transformative tool for various construction related applications (Yi and Sutrisna, 2021).

Application of drone technology in construction project management

The application of drone technology to aid multiple construction related tasks throughout the project life cycle has been explored by various studies, each focusing on different aspects and methodologies, leading to diverse conclusions. For example, Álvares, Costa, and Melo (2018) present a broad overview of drone applications throughout the construction lifecycle, highlighting their utility in pre-construction

tasks such as site surveying and mapping. In contrast, Eiris et al., (2020) specifically investigate drone usage for building inspections, revealing a narrower focus. Martinez, Gheisari, and Alarcón (2020), and Rachmawati and Kim (2022) delve into drone technology for construction progress monitoring, underscoring its potential for enhancing project oversight. However, their findings may suggest that while drones are beneficial, their effectiveness during construction execution can be inconsistent depending on site conditions and operational protocols.

Additionally, authors such as York et al., (2020) and Razafimahazo et al., (2021) explore post-construction applications focusing on maintenance inspections. Their emphasis on maintenance reveals a critical gap in understanding the long-term impacts of drone technology beyond immediate construction tasks (Asnafi and Dastgheibifard, 2018; Melo *et al.*, 2017). Evidently, drone technology can be implemented in varying construction projects including residential, commercial, civil infrastructure projects and industrial projects, before, during and post construction.

Theoretical perspective

The theoretical perspective of this study is grounded in the TOE framework, which elucidates the impact of technological, organisational, and environmental contexts on the adoption and implementation of technological innovations within organisations (Picoto, Crespo, and Carvalho, 2021; Jere and Ngidi, 2020; Chiu, Chen, and Chen, 2017). These settings are utilised in forecasting the intention of organisations to acquire and execute technology (Jere and Ngidi, 2020). The technological context describes internal practices adopted by organisations, current technologies in use, and external technologies available in the market (Hanson and Olsson, 2020). This context is based on technology adoption qualities, which are supported by stakeholders' technological skill, competency, and ICT infrastructure (Picoto, Crespo, and Carvalho, 2021). Relative advantage, compatibility and complexity of a technological setting are influential factors in determining technological strength.

Furthermore, the organisational context indicates the firm's resources and characteristics that facilitate the effective adoption and implementation of an innovation. It focuses on organisational size, embeddedness, and complexity of the management structure, as well as communication channels as determinants of an organisation's ability to adopt a technology – organisational readiness (Picoto, Crespo and Carvalho, 2021). Martínez-Caro, Cegarra-Navarro and Alfonso-Ruiz, (2020) indicate that strong support from top management is crucial for shaping perceptions about technology adoption, as well as for providing the necessary financial resources for successful implementation. Furthermore, the environmental context examines key characteristics of an industry, including its structure, regulatory environment, and the provision of technological services (Jere and Ngidi, 2020). This aspect assesses the opportunities and challenges within the industry related to government support, competitive pressures, and external assistance.

Research Methodology and Method

Informed by the TOE framework as the theoretical underpinning, this study combines a systematic review of literature and a contextual inquiry to explore drone technology implementation in construction management. While a systematic review of literature provided a structured approach to synthesising existing studies, contextual inquiry provided nuanced, user-centered insights that may not surface through traditional survey methods, ensuring contextually tailored solutions (Saunders et al, 2016). Content analysis was used to systematically review 37 peer reviewed studies published between 2016 and 2024. This process involved a detailed review of titles, abstracts, methods and findings of studies retrieved from google scholar, EBSCOHost, SCOPUS, ScienceDirect, Elsevier, Wiley, and Springer using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) procedure similar to Albeaino et al., (2019) using NVivo14. Search terms were derived from the study's aim involving internal and external factors that influence the adoption and implementation of drone technology in construction project management. The following question enabled the development of search terms: *what are the challenges, limitations and uncertainties in the deployment of drones on construction sites?*

The contextual inquiry procedure entailed a preliminary interview session followed by the researcher's observation of a drone deployment process on three cases to gain richer interpretations of the contextual factors that need consideration in the implementation of drone technology to aid construction

related processes. Semi-structured follow up interviews were conducted with the project coordinators, including the contractor's team, client project manager and a drone operator. Consequently, interviews provided an effective means of acquiring profound insights into intricate phenomena, including varied viewpoints and producing extensive qualitative data that cannot be readily acquired by alternative approaches such as quantitative surveys (Johnson, Adkins and Chauvin, 2020; Johannesson and Perjons, 2021). A total of ten (10) participants took part in the inquiry. The main method of sampling used in this study was purposive sampling. However, due to the lack of an exhaustive database and limited practice of drone technology, snowballing was also applied (Kassu, 2020). The participants identified through LinkedIn and companies they work for were asked to identify and refer other potential participants who meet the criteria, thus creating a snowball effect (Busetto, Wick and Gumbinger, 2020).

The objective was to outline factors impacting the utilisation of drone technology on construction sites, as perceived by the construction project stakeholders, observed by the researcher, and experienced by project coordinators. The observation guide entailed observed challenges faced by the project team, challenges in real-time connectivity by key stakeholders, and any challenges faced by the drone. Interview questions were developed based on perceived and experienced organisational and technological factors. Thematic analysis was employed in accordance with Creswell and Creswell, (2018) to identify pertinent themes through the coding of observation and interview data using NVivo 14. Therefore, the following question was posed to enable the researcher to achieve the objective: *what is the nature and occurrence of the challenges to drone technology development on construction sites?*

Research Results

Challenges, limitations and uncertainties in drone deployment on construction sites

The literature review identified several key factors influencing the adoption and implementation of drone technology in construction projects. A significant challenge highlighted in the literature revolves around regulations governing drone use (Nielsen, 2017; Li and Liu, 2019; Outay, Mengash, and Adnan, 2020; Sibanda et al., 2021). Additionally, operating drones necessitates skilled professionals, as the process can be complex, making qualified operators crucial for their effective use in construction (Golizadeh et al., 2019; Mahajan, 2021; Mohsan et al., 2022). Flight reliability is also significantly affected by weather conditions (Melo et al., 2017; Falorca, Miraldes, and Lanzinha, 2021), with studies indicating that strong winds can impair navigation systems, negatively impacting flight paths (Mahajan, 2021; Mohsan et al., 2022). To enhance flight reliability and optimise efficiency, it is essential to develop a robust algorithm capable of adapting to various conditions (Rachmawati and Kim, 2022).

Similarly, Falorca and Lanzinha (2020) discovered that drones in operation could distract construction personnel, potentially compromising their safety. Conversely, studies by Ciampa, De Vito, and Rosaria Pecce (2019), York, Al-Bayati, and Al-Shabbani (2020), and Ruiz, Lordsleem Júnior, and Aquino Rocha (2021) identified a significant limitation regarding drone power capacity, which restricts flight missions to 20-30 minutes with an hour required for recharging. Consequently, the existing literature outlines several key considerations for deploying drone technology in construction processes, as illustrated in Figure 4.1 below. The results obtained from the highlighted in the figure below are grouped under the three (3) categories: challenges, limitations, and uncertainties. The challenges are organised under operational challenges which relate to the equipment and environmental conditions; project related challenges which encompass project delivery strategies and organisational policies; and those external to the project environment which are largely influenced by the regulatory environment. Conversely, the limitations relate to the drones's inabilities based on its software and hardware design. However, uncertainties stem from people's perceptions relating to the technology derived from either general notions or experience with the technology.

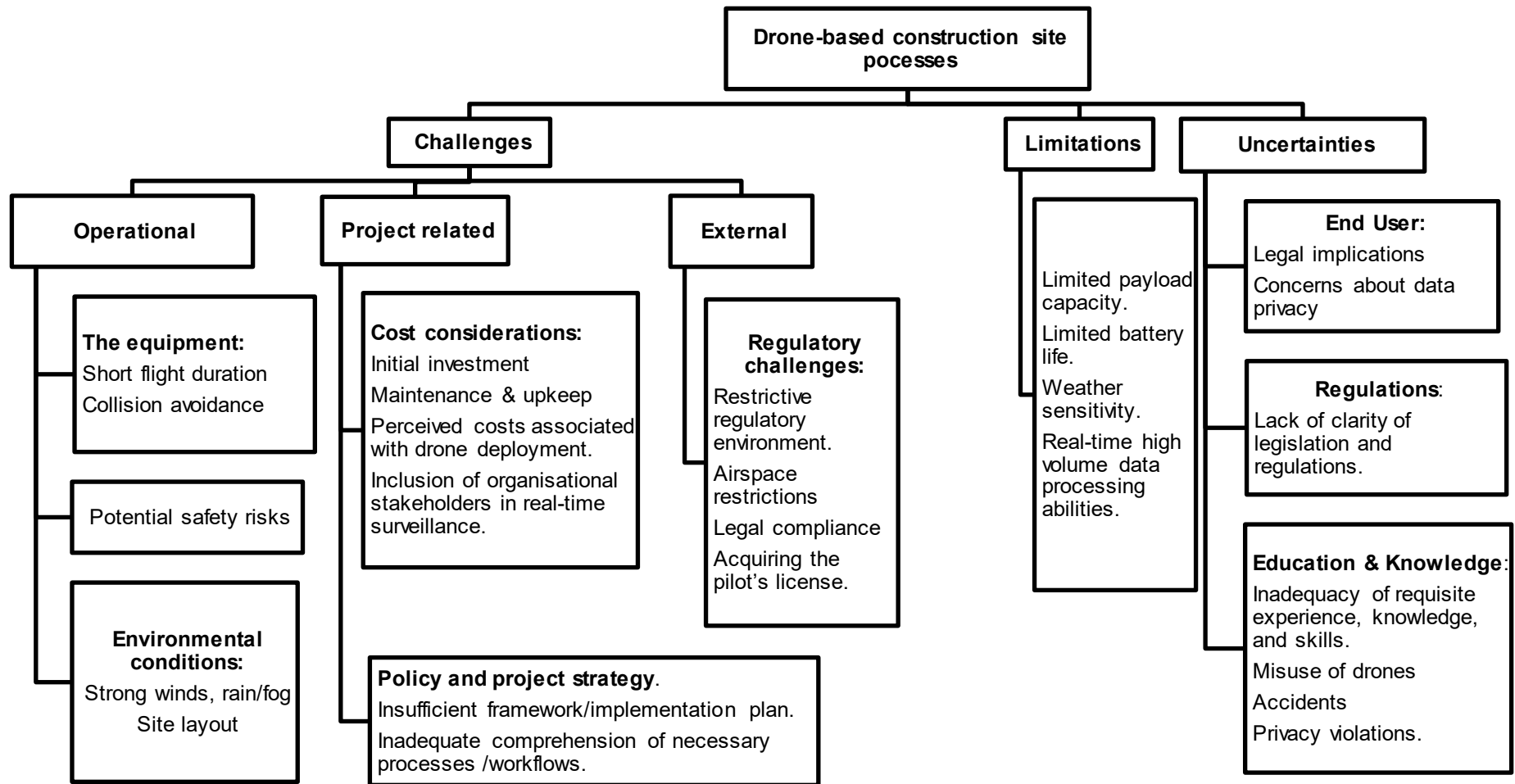


Figure 1: Drone-based construction site processes – challenges, limitations and uncertainties

The second objective aimed to identify and outline factors impacting the utilisation of drone technology on construction sites, as perceived and experienced by project coordinators. Participants were asked to indicate some challenges that they thought could hinder implementation of a drone-based approach. The question asked was answered by the 10 interviewees who are role players in the construction industry. The following perceived challenges were outlined by the 10 interviewees: Capital and resource allocation from owners (10 out of 10); Transparency and contractual accountability fears (7 out of 10); Value for money (7 out of 10); Contractor's general lack of commitment to adopt efficiency improvement tools (6 out of 10); Inspections are seen as a leadership strength of the construction manager (5 out of 10); Organisational policies (4 out of 10).

Nature and occurrence of observed challenges

Table 2 below presents the findings of challenges observed by the researcher during the deployment process. The severity depicts whether the challenges were minor (impact on inspection process could be rectified immediately; moderate (impact would cause delay, but remedial measures available on site; major (considerate remedial action required was not possible on site); or sever (extensive measures were required to remedy the challenge).

Table 2: Fieldwork observation data collection procedure

Drone-Aided Inspection Event Observation Sheet			
Brief description of challenges & occurrence	Challenge causation	Challenge Severity	Direct Immediate effects
Data acquisition challenges Low quality live visual data at certain intervals Visual inconsistencies at some locations	Poor connectivity Camera resolution, sensor accuracy	Moderate	Remote participants
Data processing & analytics Poor signal during live broadcast No immediate generation of 3D model	No automated GCPs Specialised software on large memory PC	Severe	No visual of 3D model No real time deep analysis
Ground control station disturbances Site personnel struggling to stay clear of GCS in their works	High traffic on construction site	Minor	Interference with flight plan
Flight in accordance with regulations Constant visual contact with drone throughout inspection process	Site dynamics – operator had to fly drone without direct visual contact due to obstacles.	Moderate	The drone operator had to operate BVLOS for a few minutes
Disturbance to site activities Personnel during deployment process	Personnel were disturbed by drone flying around site	Moderate	Work stoppages, loss of concentration to task at hand

Intermittent low-quality live visual data and visual inconsistencies at certain locations were observed. These hindered the reliability of data acquisition, potentially leading to incomplete or inaccurate information about the inspected area. Poor signal during live broadcast and the absence of immediate 3D model generation delayed the interpretation and utilisation of collected data, limiting the real-time response to identified issues on the construction sites. Disturbances at GCS, such as site personnel struggling to stay clear of GCS during their work was also observed. Moreover, it was a challenging for the drone operator to maintain constant visual contact with the drone due to the complex site environment. Although workers were briefed by their supervisor of the drone deployment, they still became curious. For the most part of the drone deployment their attention was fixated on the drone deployment activity.

Experienced challenges during drone deployment

Participants were asked in a follow up interview (C1P1...C1P10) to indicate any challenges they experienced during the drone deployment process. Several challenges, including connectivity issues impacting data transmission quality, battery limitations causing operational delays, and volatile site conditions disrupting operations, poor connectivity and lighting variations compromising data quality, hindering effective analysis were recurring themes. Site complexity was also highlighted as having made it difficult to define ground control station, while limited processing capabilities and software

compatibility of the drone type used were somewhat outlined as having impeded high quality real-time data processing as the type of drone (DJI Mavic 3 pro) used is an entry level industrial drone.

Discussion

The literature review identified the applications of drones across various stages of the project life cycle, including pre-construction tasks such as site surveying, mapping, and planning, where they offer advantages over conventional methods like total stations and GPS devices. As such, factors influencing the implementation of drone technology in construction project processes are variables that impact the effective implementation of drone-based construction processes. In that regard, the way these issues occur has consequences to drone applications in the construction industry. The challenges encountered during the deployment of drone technology through the case study shed light on various operational and logistical constraints that were identified in literature. Connectivity issues emerged as a common challenge, affecting data transmission quality and remote participation. Battery limitations posed some hindrance, particularly when covering extensive inspection areas, necessitating efficient battery management strategies to mitigate delays and maintain output quality. Data quality concerns, exacerbated by connectivity issues and lighting variations, underscored the importance of stable connections for reliable data collection. Volatile site environments, marked by unresolved disputes and community involvement, posed security risks and operational disruptions, emphasising the need for effective coordination and conflict resolution strategies.

Furthermore, ground control points and terrain complexity posed technical challenges, especially with the entry-level industrial drone lacking automatic capabilities for defining ground control points, impacting the accuracy of mapped models. Processing delays and rendering inefficiencies hindered real-time data analysis and 3D model generation, pointing to the need for fit-for-purpose drone tools. Incompatibilities between drone AI and existing software platforms posed integration challenges, necessitating advancements in technological compatibility. However, rapid data collection posed challenges for real-time evaluations, highlighting the importance of enhanced data interaction and accessibility features. Additionally, determining suitable ground control station for take-off and landing proved challenging in a complex site environment. Overall, challenges encompassed various aspects, including technical, regulatory, operational, and organisational factors, emphasising the nature of challenges to the implementation of drone technology in construction projects.

Conclusion

This paper provided an analysis of the factors that affect implementation of drone technology in the construction industry and categorised these aspects under the technological, organisational, and environmental contexts. This study sought to provide valuable insights for researchers and professionals within the context of South Africa. The study advanced the understanding of drone technology applications in construction project management, particularly focusing on its potential for enhancing and streamlining construction works. By presenting the nature and impact of challenges to drone technology deployment, the research set a foundation for future studies on drone-based processes during construction execution in South Africa. Moreover, the research provided an exploratory platform for understanding the challenges hindering the optimal utilisation of drones on construction sites. Thus, this paradigm establishes the imperative to fully integrate drone technology into the South African construction industry, focusing on its significant transformative potential while proactively addressing existing challenges. Hence, there is a need to drive collaboration between academia and industry experts, to actualise the adoption of innovative drone solutions that not only revolutionise construction processes but also deliver substantial improvements in project efficiency and outcomes.

Recommendations

Given the diverse applications of drone technology in construction, it is essential to foster interdisciplinary collaboration among experts in engineering, construction management, and aviation to drive innovation. To accelerate the adoption of drone technology in South Africa, the establishment of pilot projects focused on addressing local construction challenges such as improving access to remote sites and monitoring large-scale infrastructure development should be prioritised. Collaboration with the South African Civil Aviation Authority (SACAA) is vital to simplify and adapt regulations for drone use in

construction. Streamlined regulatory frameworks will help remove bureaucratic barriers, enabling smoother integration of drones in project management. Additionally, incentivising industry-driven research through government grants can promote collaboration between academia and industry. This could allow the validation of research findings and accelerate the adoption of drone technology in the local context. Intrinsically, promoting local capacity building by introducing skills in drone operation, maintenance, and data analytics. Ultimately, ensuring the effective use of drones in construction processes can accelerate drone integration, enhance project efficiency, and address local industry needs effectively.

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The Application of Cyber-physical Systems Towards Improved Project Outcomes: an Industry Perspective

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Abstract

This research paper examines the impact of digitalisation, particularly Cyber-Physical Systems (CPS), on construction projects to improve project outcomes. Its main aim is to clarify the concept of CPS and investigate how it is used in the design and construction stages, towards efficient project delivery and reduced waste. The study also aims to identify the challenges of implementing CPS and the advantages of its adoption. The research uses a single-method qualitative approach, focusing on detailed interviews and a thorough review of pertinent literature. Data is gathered from professionally registered industry professionals who hold managerial positions. This qualitative analysis investigates the concept of CPS and its possible applications in design and construction, providing valuable insights into the participants' experiences and viewpoints. The research highlights that CPS can potentially transform the construction industry significantly. Qualitative analysis identifies financial limitations, skill shortages, and data security issues. However, the advantages of adopting CPS, such as enhanced productivity, reduced design fragmentation, shorter construction times, and better quality clearly surpass these challenges. There is an acknowledgement that using a single-method qualitative approach may restrict the generalizability of the findings, as they are specific to the given context. Additionally, there may be potential bias in the participants' responses. This research provides valuable, context-specific insights for construction professionals, policymakers, and industry stakeholders. It highlights the need to invest in CPS and develop a skilled workforce to realise its transformative potential fully. The quantity surveying profession can utilise CPS to improve cost control and management by tackling the challenges and maximising the benefits. This paper contributes to the existing knowledge by offering an in-depth understanding of CPS within the construction industry based on a single-method qualitative approach. It serves as a key reference for those exploring the potential effects of CPS on construction and design in the South African context. Furthermore, there is a focus on the positives derived from CPS that the quantity surveying profession, in particular, can benefit.

Keywords: Cyber-Physical Systems, Construction industry, Project Delivery, Digitisation, Efficiency.

Introduction

Construction is the world's largest industry, consuming around one-third of all raw materials and generating a similar proportion of waste. It also accounts for 35-40% of all global greenhouse gas emissions (Brozovsky et al; 2024). According to Musarat et al. (2024), the construction sector has been mostly dependent on manual labour, which results in increased labour costs and time consumption on the job site. Consequently, there has been a decrease in productivity. Agnesia et al. (2024) assert that the construction industry has benefited greatly from the adoption and use of the Fourth Industrial Revolution (4th IR). Modern technology has been introduced to the industry by the 4th IR. This technology includes construction models, software, and mechanical technology that help with project drawings, designs, and specifications. As a result, productivity has improved and project schedules and marginalised profits have improved (Msilmani et al., 2024).

The 4th IR involves the continuous automation of traditional manufacturing and industrial processes through advanced smart technologies. Cyber-physical systems (CPS) are technical setups where

interconnected computers and robots engage with the physical environment for improved outcomes (Jaafar et al, 2021). In an era of rapid technological advancement, the merging of the digital and physical domains has resulted in the development of Cyber-Physical Systems (CPS), which have the potential to revolutionise industries worldwide. Nonetheless, Ikuabe et al. (2020) claim that South Africa's construction sector has been reluctant to adopt new technologies, such as Cyber-Physical Systems (CPS). Due to its significance and contributions to GDP, the construction industry is one of the key sectors responsible for a nation's economic growth among those ripe for significant transformation (Masoetsa et al., 2022). Furthermore, while the construction sector boosts the GDP of an economy, it also generates a lot of waste (Jaskula et al., 2024). This then provides an opportunity for the construction sector by leveraging on the benefits provided by CPS to aid in reduced wastage and enhanced cost planning and management throughout the projects' lifecycles.

Physical and non-physical waste are the two types of construction waste (Khodabakhshian et al., 2022). Omer et al. (2022) describes physical waste, commonly known as "waste during construction," as the solid debris generated from building, demolition, and renovation activities. Yuan et al. (2024) further define non-physical waste as the loss of capital, labour, materials, equipment, and resources resulting from cost operations that do not enhance the value of the customer's product. They also estimate that South Africa will produce between 5 million and 8 million tonnes of construction waste annually. Additionally, construction waste undermines sustainability efforts and has a detrimental impact on the environment (Wang et al., 2024). When we think of our industry, we need to consider the triple P-bottom line which consists of people, planet and profit. Campos (2020) mention that we also need to consider how cyber physical systems can improve the triple P bottom line.

The Council for the Built Environment (CBE) Identification of Work (IdoW) Content Framework (2020) document which guides the work for all industry professionals, proposes that all industry professionals registered under Act 43 of 2000 spent over 55% of their project inputs on two project stages, being work stages three (3) and five (5), commonly known as the Detail Design or Development and Construction Documentation and Management. Key decisions pertaining to specifications, process flow of work, constructability requirements, costing and resourcing models are finalised at stage three (design). A linear trajectory is therefore created whereby the implementation of the project at stage 5 (construction) is linked directly to the outputs of work stage three (design). This reality provides clarity that positive impact by utilising CPS during construction stage cannot be attained without first addressing the application of CPS during design stage as that dictates the level application of CPS that can be adopted during construction stage towards increased productivity and waste reduction.

The research problem the paper seeks to address is how best to improve efficiency in the local construction sector by increasing productivity and reducing waste. The researcher explores the application of CPS to address these challenges. The primary research question of this study examines how CPS is impacting the construction industry. The sub-questions are: What are the uses of CPS in design and construction? What factors facilitate the adoption of CPS in these fields? What obstacles hinder the implementation of CPS in design and construction? If the adoption of CPS is ignored, the construction industry will still be considered one of the slowest performing industries that produces bulk wastes, cost overruns and an increased negative image of the role players, including the project accountant (QS).

Literature Review

Quantity surveying is an excellent career option for both men and women interested in the dynamic field of construction and development. The role of a Quantity Surveyor (QS) has become even more vital today compared to its origins in England in 1785, due to the high-pressure environment characterised by rapidly escalating costs and significant growth (Adbin, 2021:12). Measurer, custom surveyor, and surveyor were the terms in use before the term QS being first documented in 1859. When the building owner received the Final Accounts from the skilled craftsmen, the QS measured the completed work. These actions increased the likelihood that building owners would hire a contractor and would get bids before starting any work (Qureshi et al., 2022). When constructing a structure, building owners would also work with architects and engineers. Specifications and drawings were sent to a selected collection of master builders, who were then requested to provide quotes for the entire cost as opposed to a compilation of master tradesmen's rates (Wuni et al., 2024). The digitisation of the production environment has made it feasible to deliver accurate information to the appropriate person at the appropriate moment in a more flexible manner. This could guarantee that the professional practice of

quantity surveying fulfils its goal of becoming faster and more precise in its understanding of the changes that are taking place (Makhathini et al., 2022).

According to Chang et al. (2024), despite the industry's strong need and significant sustainable improvements, the QS profession is hesitant to integrate the novel 4th IR technologies into standard project processes. There will be a big impact from the 4th IR on the QS field. Despite the practical and obvious advantages that the fourth industrial revolution (Khatleli, 2018) brings, the construction sector as a whole is still having difficulty implementing these concepts in projects. The construction sector faces several significant problems in adopting the Fourth Industrial Revolution (FIR) such as fragmented supply chains, short-term thinking, complexity, uncertainty, and cultural extinction (Nkosi et al., 2020).

With the use of mobile devices to connect a vast number of people with previously unheard-of levels of processing power, storage capacity, and information access, the 4th IR has begun its process of bringing people and technology together (Ghimire et al., 2024). The widespread automation of the 4th Industrial Revolution reduces the necessity for human involvement in the workplace, leading to significant implications for policy and planning (Gurgun et al., 2024). This technological shift should be viewed as an opportunity for work to become a means for people to reach their full potential, rather than as a competition between humans and machines. Khatleli (2018) notes that quantity surveying focuses on building work measurement, cost estimation, and project financial management. As a result, Quantity Surveyors possess a deep understanding of construction projects and their financial management. Therefore, the 4th IR improves the QS by being efficient and making sure the QS guarantees the successful acquisition of the project deliverables (El-Kady, 2023).

The construction industry has seen an enormous increase of 4th IR digital technologies, which are gradually altering the ways in which infrastructures, real estate, and other construction facilities are planned, built, run, and maintained (BuHamden et al., 2021). Several successful projects have been the consequence of the 4th IR's deployment of various construction technologies, which were crucial in project design and cost estimation (Abutaha et al., 2024). The 4th IR strengthens the crucial function of the QS by guaranteeing that the construction project is completed on time, within budget, and in compliance with the designated plans and specifications (AlBakhy et al., 2024). Moshood (2024) added that contractors and consultants engage Qs to help with the following tasks: project budgeting, tendering, and bidding assistance, valuing the contractor's construction work, and sending bills or expenses to the client for payment processing. According to Kane et al. (2023), this merely suggests that the QS can expand into any building field they choose because of their prior training.

CPS defined

According to Giaimo et al., (2020), a cyber-physical system is described as one that combines computational and physical elements to develop new tasks and functionalities that neither component could accomplish on its own. El-Kady et al., (2023) describe CPS as a system that involves electronic monitoring, control, and operation in conjunction with a physical system. According to Kim (2020), CPSs are formed by the seamless integration of cyber and physical components. The cyber components manage processing and communication through the cloud, while the physical components consist of wireless sensor networks that sense and interact with the real world. Tonelli et al., (2021) emphasise that connectivity is essential for CPSs to enable communication between their physical and cyber elements, with technologies such as Ethernet, Bluetooth, and Wi-Fi facilitating both wired and wireless connections.

Advantages of adapting CPS

The enablers of application of CPS in the construction industry are listed in the table below.

Table 1: Advantages of CPS in design and construction

Enablers of CPS	Source
Efficiency	(Anumba et al., 2024), (Gurgun, 2024), (Zhao et al., 2020)
Collaboration	(Garcia et al., 2019), (Vaz, 2024), (Jaskula et al., 2024), (Mokhojane et al., 2022)
Improved quality control	(Gomez et al., 2024), (Khodabakhshan et al., 2024), (Karaca et al., 2024)

Workers' productivity and safety	(Alantunji et al. 2021), (Jaafar et al., 2024) (Jaskula et al., 2024).

From the above literature, it can be ascertained that the application of CPS in design and construction can lead to improved efficiency in project delivery. There is a lot of fragmentation at design stage between different professionals, the gap can be closed through better collaborative methods. Most importantly, there is an improvement in quality and the safety of workers.

Disadvantages impacting on adoption of CPS in design and construction

While CPS has many advantages, it also comes with a number of drawbacks. These barriers to adoption are listed in Table 2 below.

Table 2: Disadvantages of CPS in design and construction

Barriers of CPS	Source
Complexity	(Alnaser et al, 2024), (Oke et al., 2024), (Kane et al., 2023)
Security	(Chang et al., 2024), (Gurgun et al., 2024), (Leonard et al., 2024).
Integration and/or interoperability	(Agnesia et al., 2023), (El Kady et al., 2023), (AlBalkhy et al., 2024)
Implementation and Maintenance Costs	(Msilmani et al., 2024), (Ghimire, 2024), (Abutaha et al., 2024)
Fragmented industry structure	(Moshood, 2024), (Jaskula et al., 2024), (Anumba et al., 2024),
Low investments in Research and Development (R&D)/Education & Training	El-Kady et al. (2023), (Wuni, et al., 2024), (Gomez et al., 2024),
Legal and Contractual uncertainty	(Mokhojane et al., 2022), (Masoetsa et al., 2022), (Anumba et al., 2024),
Regulatory compliance	Mokhojane et al., 2022), (Gomez et al., 2024), (Jaafar et al., 2024)

From the above literature, it can be ascertained that there remain numerous hurdles to the application of CPS towards improved project outcomes. There is a level of complexity to most of the technologies contained within both the cyber and the physical sides of this ecosystem. This level of complexity may be usage, familiarity or integrating two or more technologies of a defined purpose, this may require a certain level of skillset which can be attained through upskilling and focused training. Low investments in research and development contributes to the low levels of skillset and general resistance to adoption. Fragmented industry structure between the role players makes it more challenging to attain acceptance between the different stakeholders. Legal and contractual uncertainty remain a limiting factor due to existing guiding documents such as the common contract documents (JBCC, GCC, NEC etc) that do not make room for implementation using CPS. Regulatory compliance remains a challenge due to key legislative documents such as the CIDB Practice notes and SANS specification documents not updated to reflect how CPS can be incorporated in design and construction.

Improved overall project performance through CPS

There is significant literature that supports the application of CPS in construction results in improved project delivery ((Anumba et al., 2024, Gurgun, 2024, Zhao et al., 2020, Mokhojane et al., 2022, Chang et al., 2024, Gurgun et al., 2024, Leonard, et al, 2024). Similarly, the quantity surveyor plays a key role in construction projects by estimating and monitoring construction costs (Weerasooriya; 2024). Consequently, this research provides insight into how each of the construction professionals can best benefit from incorporating CPS. For the benefit of this article, the section below provides insight aimed specifically at the enhancement of the role of Qs by integrating CPS.

Focus on CPS value driven quantity surveying functions

The QS is empowered by legislation to also play the role of either Principal Consultant (PC) or Principal Agent (PA), making them a key decision maker in construction projects. The South African Council for

the Quantity Surveying Profession (SACQSP) Guideline for Tariffs of Professional Fees 2015 (SACQSP, 2015) explains the PA role as meaning the entity designated by the client to oversee and administer the contract between the employer and a contractor for the execution of the project or its components.

So as to prevent delays, cost overruns, or safety risks, the PA is crucial in recognising and resolving any difficulties or problems that may come up during the construction process (Oberlender et al., 2021). According to Qureshi et al., (2022) physical process supervision is the most popular method for keeping tabs on the status of construction projects. This process of supervision incorporates regular site progress meetings and visits, scheduling updates as well as daily or weekly reports. In order to illustrate the various stages of the completed building project, the progress report also includes photos of the completed construction work (Msilmani et al., 2023). Arabia, 2023 denotes that supervisors monitor the works carried out, inspect the material quality utilised and ensures the construction is adhering to the plan at hand.

The above paragraph identifies numerous reports, actions and processes undertaken at contract administration stage. Quantity Surveying functions which are regarded as traditional at contract administration stage can be improved by the incorporation of numerous CPS not limited to blockchain technology, drone and aerial imaging technology, laser scan technology, building information modelling and generative artificial intelligence etc to name a few. In support, BuHamdan et al., (2021) and Musarat et al., (2024) emphasise their contribution to promoting project efficiency and sustainability.

Studies by Karaca et al., (2024) and Khodabakhshan et al., (2024) show that blockchain technology has great potential to address transparent and secure transaction management challenges in building projects. The benefit for the quantity surveying profession provided by blockchain technology are numerous in relation to contract administration, specifically the core services of quantity surveying related to construction stage such as (1) establishing and maintaining a financial control system, (2) preparing valuations for payment certificates to be issued by the principal agent and (3) preparing schedules of predicted cash flow. Blockchain technology can be beneficial to the quantity surveyor in the following ways: blockchain technology is an enabler of smart contracts through which speedy payments can be initiated to the contractor when certain milestones are reached as opposed to onsite measurements for purposes of determining works valuations. For this proposed block-chain linked valuation system to work, it would have to be paired with other digital technologies that enable a smart construction site such as BIM, Big Data Analytics and Cloud Based Data Management Systems (Mokhojane et al., 2022).

BIM is another crucial technology that aids remote construction management. BIM software creates detailed 3D models of the construction project, integrating data from various sources to provide a comprehensive view (Leonard et al., 2024). These models help in planning and visualisation and play a vital role in clash detection, identifying potential conflicts between different systems such as plumbing and electrical before they occur on-site (Jaskula et al., 2024). This proactive approach reduces costly rework and delays. However, for specific quantity surveying functions 4D and 5D BIM may add value to the QS. There is also a possibility of whether 4D BIM paired with Blockchain could make cost management and control a faultless and efficient exercise to provide clients with cost certainty at every auto-generated valuation.

4D BIM helps the quantity surveyor (QS) who has transitioned to a project administrator (PA) by facilitating the scheduling and sequencing of construction tasks and milestones. It adds the "time" dimension to spatial models, allowing elements to be visualised as they are introduced according to the project timeline. This approach shows which components have been demolished, completed, are in progress, or are upcoming. With 5D BIM software, project teams can integrate cost information into almost every model element and assess how changes in materials will impact the project's overall cost. The benefits of tight cost management and control provided by the QS function would be numerous to clients. The possible interoperability between 4D BIM, 5D BIM, blockchain, drones and Gen AI can provide the QS function with exceptional leverage towards efficiency during cost management and control during construction.

According to Makhathini et al., (2023), PAs and Qs can now monitor progress and costs effectively without being physically on-site, thanks to advancements in cyber-physical systems (CPS). Drones and aerial imaging have also become essential tools in construction management. Drones equipped with

high-resolution cameras can perform site surveys, capturing detailed aerial images and videos (Hull, 2022). These images provide up-to-date visual information on site progress and conditions, allowing managers to monitor the site remotely. Regular drone flights can document progress over time, creating a visual record that can be compared to project schedules, ensuring that the work is on track (Oke et al., 2024). The possible interoperability between drones, 5D BIM, blockchain and Gen AI can aid further the process of timely and accurate valuations by the QS and the PA. Drones can capture at any point in time, live visuals from a construction site, the drone when paired with GenAI can transfer the imagery scanned from site, to a 5D BIM which would compute a quick valuation and transfer the valuation amount to a blockchain system which would trigger immediate payment releases on the attainment of set milestones.

Methodology of Research

The paper embraced an interpretivism research philosophy, which was ideal for examining the personal experiences, perceptions, and social contexts of professionally registered construction professionals in the construction industry concerning improved project performance outcomes through CPS. The identified individuals are in managerial roles within construction projects and are therefore perfectly placed to share insights pertaining to the challenges of integrating CPS in construction and design, and to identify potential solutions for these challenges.

Table 3: Summary of research methodology adapted by researcher

Research Methodology	Selection
Philosophy	Interpretivism
Approach	Inductive
Choice	Qualitative
Strategy	Case Study
Method	Mono-method
Choice	Qualitative
Time horizon	Cross- sectional
Technique and procedure	Primary data collection

The research utilises a case study methodology, concentrating on interviewing individuals in managerial positions and analysing their behaviors. According to McCombes (2023), this method involves a thorough investigation of one or more subjects or cases within their real-world context. Vizcarguenaga-Aguirre et al. (2020) suggest that mono-method studies offer a concentrated and cohesive approach to research, enabling a thorough examination of a particular research question. These studies are generally simpler to design and carry out because they do not involve combining multiple methods. In this case study, data gathered from semi-structured interviews with managerial staff was analysed to explore the potential advantages of adopting CPS in design and construction phases for improved project outcomes. Based on the findings, the researcher developed a set of recommendations.

Data collection and analysis method

Thematic analysis was used to identify and analyse recurring themes. Coding and Categorisation: Data was organised into sub-themes in alignment to the research objectives (Theme 1, 2 and 3 respectively). Professionally registered individuals consisting of project managers (5), civil and structural engineers (5), electrical and mechanical engineers (5), architects (5), quantity surveyors and construction managers (5). with managerial roles in Bloemfontein, Free State. The sample size had targeted thirty professionals. The study reached data saturation at 14 participants. The interview process was conducted face-to-face and online via Microsoft Teams with the participants. The participants received the interview protocol and consent form sent in advance and they were assured anonymity. The data gathered from the participants was examined through transcription and thematic analysis to uncover recurring patterns.

Research Results and Discussions

The section below provides the results and findings of theme 1, whereby, familiarity to CPS concept by the professionally registered stakeholders was investigated. Different CPS application was noted in a few respondents at different stages of the project's lifecycle.

Theme 1: The application and adaptation of CPS in practise.

In relation to this theme, the interviewees were asked about how they use and adapt CPS within their professional roles. The interviews indicated that many professionals had a minimal grasp of CPS in the construction sector. Most were familiar with just two particular CPS elements: drones and the emerging Building Information Modelling (BIM) systems, which are becoming increasingly popular. The following sub-themes are discussed.

The utilisation and adaptation of CPS

Respondents 1, 3, 5, 8, 10, 11, 12, and 13 report that they have integrated a form of CPS into their work. Among them, Respondents 1, 12, and 13 specifically mentioned that they have adopted and utilised the BIM model in their areas of expertise. Furthermore, Respondent 1 highlights that he uses CPS to quantify and estimate based on the architectural drawings provided by the architect. Conversely, Respondent 12 says she utilises the system to design and create a 3D model of the structure at hand as supported by literature from Weerasonya et al., (2024) and Kharche et al., (2024). Respondents 11 and 13 go on to explain that because virtual reality (VR) works with BIM, they use it to give clients a realistic sense of the space throughout the planning stages. Respondent 13 goes on to say that he makes use of BIM mostly from the conception and viability stages to the close out stages of the project.

Respondents 8 and 13 indicate that they have adapted CPS in a form of drones as per the literature work done by Jaskula et al.; (2024) and Ghimire et al., (2024). Respondent 8 emphasised that they evaluated the work progress on the site using drones; Respondent 13 says that drones are their main tool for evaluating construction sites. Respondent 13 further says *"the only form is through drones but the only extend we have used drones for is to establish site boundaries and the overall layout especially when it comes to existing infrastructures so that we can know exactly what the position of the elements on sites that actually inform your design, how they are positioned, how far they are from possible existing services and so forth. So, we usually use drones for reference. The same implication that googles earth has, just that drones are a lot more updated."* Additionally, respondent 2, 6, 10 claim that they have not utilised CPS but have seen and heard about drones.

Beyond that, Respondents 3 and 5 indicate that they have used CPS in the form of a digital measuring tape. Both respondents highlighted that the digital tape was used to take measurements for site establishment and site works completed. *"I would not really consider it an update CPS because I still have to sit down and prepare the progress report because the tape is not connected to any cloud of the project data"* says Respondent 5.

Required skills

When asked if there are any skills expected in utilising CPS efficiently, most of the respondents acknowledged that certain skills are vital. Respondents 3 and 6 say one must have computer and IT skills, respectively. According to Respondents 2, 4 and 5, 7, 9, 10; CPS utilisation only requires skills that can only be offered through training. On the contrary, respondents 12 and 13 hold the view that before utilising any CPS, one must possess skills in robotic operations and computer-aided design. *"BIM is not immune to error. It is important to have an eye for detail because if the architect updates a section from their side, you must see if the quantities and estimates align with the standard system you have updated or not. Otherwise, it is an error"* Respondent 1 added. The above are supported by the following literature by El-Kady et al. (2023), Wuni, et al., (2024) and Gomez et al., (2024).

These are consistent with research by Kane et al. (2023) showing that developments in artificial intelligence, automation, robots, and the Internet of Things (IoT) are driving these improvements. The previously mentioned findings suggest that robotics and automated system operation training is required for professionals intending to adapt CPS. In addition, Jaafar et al. (2024) emphasise that an understanding of IT structures and security design are necessary to protect the privacy and reliability

of information and processes. This is consistent with the comment from respondent 6 who stated saying *“a little bit of IT skills are required to operate such systems. I do not know if anyone can operate a gadget these days without IT skills. You know such a system will help us work remotely and monitor what is happening on site.”*

The findings are consistent with how CPS is defined in the literature. With Giaimo, et al (2020: 1) expresses CPS as systems that combine real (mechanical or biological) and cyber (computational) components to produce novel functions and features that neither of these systems could produce independently. Additionally, the findings pertaining to this issue also demonstrate the professionals' limited knowledge regarding CPS, since they identify emails and Microsoft Project as CPS.

Theme 2: Disadvantages of adapting CPS in design and construction

This theme highlights the difficulties professionals encounter when integrating CPS into their work. The respondents focused on problems associated with CPS implementation, such as complexity, technical constraints, integration issues, interoperability challenges, and cybersecurity threats. They identified several obstacles associated with CPS, such as costs, required training, regulations and policies, and physical characteristics. The following sub-themes are discussed.

Reluctance and preference

Respondents 1, 2, and 4 stated that there was some reluctance because they were accustomed to the manual techniques when questioned about the difficulties, they had implementing CPS in their field of work. *“Change is not easy, so it took time to adapt and get used to BIM but eventually we got it right,”* said Respondent 1. Respondent 4 states *“...there was a need for training when implementing the digital measuring tape for site measurements, there were technologically savvy individuals and there was some sort of resistance to the conversational method.... the outdated individuals were also a problem.”* Respondents 1, 2, 3, 8, 11, 12, and 13 also mentioned that training was necessary because the systems were unfamiliar to them. One respondent stated, *“just like there is a need to undergo training for WinQS, we had to be trained on how to use the drone.”* Literature review also supports this barrier as stated by Msilmani et al., (2024), Ghimire (2024) and Abutaha et al., (2024).

Expenses

According to responses 3, 6, 7, 10, and 11, the expenses linked to the sophisticated technology present another drawback of adopting CPS. In reference to budgetary expenses, Respondent 6 mentions that *“To have Revit, it is yearly license, where some of the design programs, there are options that we buy two licenses, but five have access to it simultaneously.”* However Respondent 3 refuted the notion that prices are a barrier, stating that drones are less expensive than the expenditures associated with human management and inspection.” Literature review also supports this barrier as stated by Msilmani et al., (2024), Agnesia et al., (2023), El Kady et al., (2023) and AlBalkhy et al., (2024).

Cybersecurity

The findings also indicate that respondents 1 and 3 encountered a cybersecurity threat. These respondents had to hire IT experts to assist them with cybersecurity threats they faced when hackers attempted to access their systems. Respondents 2, 5, 7, 10, 12, and 13 argue, however, that they have not experienced any threats from hackers because their IT departments have kept their maintenance system up to date. .” Literature review also supports this barrier as stated by Chang et al., (2024), Gurgun et al., (2024) and Leonard et al., (2024).

Policies and Regulations

The findings also show that policies and regulations impose barriers to system adaptation. The “red tape” that the South African government implemented is cited by respondents 12 and 3 as a drawback. On the contrary, respondent 9 says “If private organisations or a public entity could implement CPS and integrate it into our work, we could adapt and benefit from it.” On the other hand, respondent 6 thinks that rules and policies, being subject to frequent changes, are not necessarily an obstacle. Literature review also supports this barrier as stated by Mokhojane et al., (2022), Masoetsa et al., (2022), and Anumba et al., (2024).

Physical Characteristics

One of the drawbacks of utilising CPS on site, according to respondents 2 and 8, is the physical characteristics of the weather, such as strong storms and rain. Respondent 8 says. *“Not unless there are those models that can work under heavy weather like when you are having storms”*. Respondent 7, however, emphasises that loadshedding presents a problem because it occurs often and can result in network disconnections. Literature review also supports this barrier as stated by Mokhojane et al., (2022), Gomez et al., (2024) and Jaafar et al., (2024)

Majority of the respondents were reluctant to adopt CPS due to fragmentation issues during planning and design development. Respondent 2 highlighted *“In terms of collaboration, interactions can be done from the onset but there are limitations due to the preference from the consultants....You might have someone who has been using CAD for 19 years, and you come using Revit, you need to make sure that whatever that you are using is converted to the same format that they will be able to work on.”*

Theme 3: The advantage of utilising CPS in design and construction for professionals.

The Interviewees who have used CPS noted that these systems have improved the efficiency and precision of design and construction processes. They frequently highlighted benefits such as more efficient project timelines, quicker project oversight, and enhanced collaboration and communication with stakeholders. The following sub-themes are discussed.

Collaboration and communication

Respondents 11, 12, and 13 have identified improved collaboration and better communication as advantages of adapting CPS. Additionally, Respondent 1 highlights that CPS can automatically detect conflicts, eliminating the need for manual identification. Moreover, Respondent 12 mentions that CPS effectively conveys updates from other professionals involved in a project. The results also emphasise that adopting CPS significantly improves project management practices. According to respondents 2, 8, and 9, CPS enhances both time management and reporting efficiency. Additionally, respondent 9 points out that the ability to access progress information remotely minimises the need for lengthy on-site visits. Respondent 2 illustrates this with an example, stating, *“Using a drone allows you to oversee the site without being physically present at the location of the activity. You can manage it from afar.”* The findings regarding improved collaboration and better communication align with the study of Brozovsky, et al. (2024). Their research also emphasises the role of a shared platform for communication and data exchange within CPS, which enhances teamwork and supports more informed decision-making. As a result, this contributes to greater productivity among professionals.

Conclusion

The findings reveal a mixed level of understanding and implementation of CPS among these professionals, highlighting both the challenges and opportunities that come with integrating CPS in construction industry. Many construction professionals are only familiar with specific CPS components like drones and BIM, indicating a need for broader education and training. There is also a noticeable hesitation to adopt CPS due to a preference for traditional methods and the perceived complexity of new technologies. Furthermore, it is denoted that high costs, cybersecurity concerns, regulatory constraints, and physical limitations (e.g., weather conditions) hinder the adoption of CPS. However, effective CPS use requires specific skills, such as IT, computer-aided design, and advanced system operation, highlighting the need for targeted training programs. Significantly, CPS can improve project timelines, enhance stakeholder collaboration, improve project monitoring, reduce waste, and increase sustainability. It also offers opportunities for efficiency, safety, and work quality improvements, as well as skill development and increased competition among bidders.

Recommendations

In South Africa's construction industry, several recommendations can significantly advance the adoption and integration of Cyber-Physical Systems (CPS). The following should be recommended.

- Developing comprehensive educational programs aimed at construction professionals is crucial. These initiatives should cover technical aspects and practical applications of CPS, fostering a

deeper understanding and skill enhancement across the sector through collaboration among educational institutions, industry associations, and government bodies.

- Promoting CPS benefits through awareness campaigns and pilot projects is essential to demonstrate how CPS can improve project timelines, collaboration, and reduce operational costs.
- Addressing cost barriers by reducing initial implementation costs through subsidies or incentivised funding models is also vital to ensure accessibility for both large and small construction firms.
- Enhancing the regulatory framework is necessary to simplify approval processes and ensure compliance with industry standards and safety regulations, facilitating smoother integration of CPS technologies.

Further research should explore specific CPS applications throughout different project stages and investigate integration with other emerging technologies like AI and IoT to enhance overall efficiency and sustainability.

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The Effects of Late Payments by Government on Building Contractors in South Africa

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Abstract

The purpose of this paper is to communicate the effect of late payments by the client on building contractors and the effect it has on their businesses. The study, therefore examined the experiences of building contractors in the Eastern Cape. An online survey was conducted based on the effects of late payments by the government on building contractors in the Eastern Cape, South Africa. The population for this study consisted of building contractor members of the East Cape Masters Builders Association (ECMBA). The research approach adopted was deductive and entailed quantitative research to determine and analyse building contractors' operational dynamics. The results suggest that many issues, including inadequate client finance, prolonged processing time for payment documentation, and non-standard payment methods, lead to delayed payments to contractors. The findings of the empirical study showed that, despite the lack of particular laws or regulations governing the construction industry's payment systems, the sector nonetheless uses several common guidelines to guide payment practices. The research focused on the views of the contractors in the built environment within the Eastern Cape Province. The views of labour and other role-players were not considered. Improper payment methods, such as using contractors' funds for capital for construction and then claiming, severely impact the construction industry. Long payment processes additionally compel consultants to evaluate contractors' payment claims carefully. Any disruption in cash flow can induce a contractor's bankruptcy. The research found that work delays are common in the construction industry. The pay-if-paid system can be problematic for contractors because they may not always receive full payment if a project is incomplete or defective. Any interruption in the contractor's income could lead to their bankruptcy. Late payments can lead to conflicts between the contractor and other service providers. Tensions between parties could lead to negative consequences such as reduced productivity, work completion delays, and more late payments.

Keywords: Late Payments, Building Contractors, Effects, Cash Flow, Low Business Growth, The Government.

Introduction

Late payment is one of the problems faced by the built environment in South Africa. Most construction professionals are aware of the late payment issues that affect the built environment. Late payments have become so entrenched in the built environment that it is a major impediment to growth. According to the deadlines agreed between the parties of the contract, late payments are situations where payments are not made to the main contractors on time (Ramachandra & Bamidelerotimi, 2015: 43).

Connell (2014: 9) mentioned that when describing the problem of late payments, it is necessary to take into account the difference between the two interrelated concepts: the duration of payment and the delay in payment. The first refers to efficient continuation of "payment incurred by several public and private agents; the second refers to the holdup which is obtained as the deviation between the duration and the agreed contractual terms." (Connell, 2014: 9) Term of payment reflects the contractual terms plus late payment.

Failure to pay contractors on time limits the contractor's cash flow and hinders business growth. Delays in payment by the contractor negatively impact the contractor's efficiency, and, as such, affect the work schedule, leading to cost overruns and time extensions (Akinsiku & Ajayi, 2016: 4). The construction

sector is capital intensive, and the capability of clients to pay contractors on time alleviates cash flow issues for contractors (Akinsiku & Ajayi, 2016: 5). Failure of clients to provide regular and timely payment can delay the project, reduce profitability and in excessive instances the company could be liquidated.

As mentioned by Connell (2014: 7) late payments can result in tighter financial conditions, leading to higher administrative and financial costs as external funding may be necessary to manage cash flows. Consequently, late payments can lead to insolvency and ultimately bankruptcy, which means that firms cease to exist or exit the market. Since contractors might have no choice but to seek financial help from a bank, it means that the client owes the contractor and the contractor ultimately owes the bank. The profitability of the contractor depends on how actual payment is received from the client.

Construction projects have multiple construction contracts that must be signed by different parties that make up the hierarchical payment structure. Payments are a critical element of construction contracts (Hughes, Champion & Murdoch, 2015). Not only is the payment process further extended by multiple parties in the payment hierarchy, but communication problems are also uncontrolled between the various stakeholders. Late payment contributes to distrust among stakeholders in the built environment. The relationship between the client and contractor continues to deteriorate due to late payments and non-payment. According to Manu, Ankrah, Chinyio and Proverb (2015: 1495) trust is essential in order to benefit from supply integration and collaboration in the construction industry (Manu *et al.*, 2015: 1495). As stated by Okeyo, Rambo and Odundo (2015: 325) it is important for contractors to be paid on time to ensure continuity of works and completion of projects. In view of this, it is necessary to plan the payment of contractors by taking appropriate measures against potential risks. Involvement of stakeholders at the national, project and community levels is needed to mitigate those risks (Rwelamila, 2017).

The aim of this research is to communicate how building contractors are impacted when clients fail to make payments on time. The objectives of this study are as follows:

- To provide a better understanding of the consequences that the government's late payments have on building contractors in the Eastern Cape Province.
- To identify reasons for late payments and how it affects the cash flow of contractors.
- To examine the implications of late payment and the effect it has on business growth.
- To determine the reasons behind loss of productivity on site caused by late payment.

This research has the potential to assist clients and other stakeholders in resolving a number of challenges pertaining to late payments in the built environment.

Literature Review

Late payments in the construction industry

Late payment of invoices has a number of detrimental repercussions on the construction industry, mainly on contractors' ability to carry out projects, their negative cash flow, and their issues with profitability (Jiang, 2014). According to Sadler (2015), more than one-third of main contractors receive payment more than 60 days after sending out invoices. Other authors (researchers), like Ansah (2011) and Ramachandra (2013) have suggested that major contractors' adoption of 'pay-when-paid' strategies, poor financial management, and insufficient funding all contribute to the industry's ongoing problem with late payments. Another probable factor is the observation (perception) of the corrupt practices frequently connected to the construction industry (Arewa & Agyekum-Mensah, 2016).

Badroldin, Hamid, Raman, Zakaria and Mohandes (2016: 151) state that if a company does not pay within the agreed term, late payment happens. Due to late payments, organisations are unable to invest resources in development, take on new occupations, and fully contribute to nation-building. "In the most pessimistic scenarios, late payments can lead to bankruptcy. There is tension between late payment and the standard agreement." (Badroldin *et al.*, 2016: 151)

The problems in the industry are caused by the lack of large public infrastructure contracts due to the limited financial resources of the state and problematic contracts that cause losses. Industry associates

have cited the problem of late payments as a reason for many companies requesting final liquidation (Watermeyer & Phillips, 2020).

Causes for late payments

There are several factors that are provided to elucidate the occurrence of delayed payments. According to Bailey (2019: 21), the occurrence of late payments may be attributed to the prevailing business culture and power dynamics within a given nation. According to the findings of a research done by Miller and Wonsaroj (2017), delayed payments may be attributed to factors such as untimely receipt of invoices, disputes over invoice amounts, and the practice of withholding and paying invoices at certain times within the fiscal year. Payment delays on construction projects may be attributed to several factors, including the employer's unfavorable financial situation, miscommunications between the contractor and clients, and the prolonged process of acquiring the requisite certification.

Cash flow problems

Cash flow is the amount of capital a company has at any given time. It reflects the development of the company's bank account. Contractors must evaluate the client's late payment records and make provisions in their working capital calculations for a project (CIDB, 2021: 6). The CIDB report further indicates that project revenues are calculated from project costs versus project revenues. Overhead costs for the office premises and support staff are included in the contractor's cash flow requirement. This allows the contractor to predict what proportion of the capital will be required to finance the operation and repay the loans. The construction business needs a cash flow analysis (CIDB, 2021: 6). Payment terms directly affect the cash flow of a business.

The construction industry is prone to late payment culture. There is no doubt that late payment has a large impact on the participants and on the construction, since funding is the basis of any economic transaction. Late payments and non-payments directly affect cash flow which is one of the reasons why contractors ultimately source additional funding (Ramachandra and Bamidelerotimi, 2015: 43-44)(Akuffo-ntow, 2016: 16). The determined cash flow of a construction project is impaired by the clients default in payment and jeopardises the successful implementation of the project (State, 2020: 42). According to Adjei *et al.*, (2018: 37-38), the following items are factors that influence cash flow: financial risk, project claims, retention, delayed payment, sectional completion, pricing strategies, and over-measurement and under-measurement. To ensure profitability, a contractor's incoming and exiting finances must be managed effectively. The monitoring and control of the progress of the project and the management of the project cash flow can identify the benchmarks of project overruns and delays.

Effects of late payments on businesses

The development of businesses might be hindered if timely payments are not made, since it would limit their cash flow. According to Benjamin (2018), "the company's inability to generate sufficient cash flow has resulted in its inability to undertake new projects, fulfill large orders, or make investments in new equipment, all due to concerns over the potential escalation of its financial risk. Consequently, the corporation experiences a decline in its competitive advantage. The allocation of resources, both in terms of financial investment and time, towards the pursuit of unpaid clients would hinder the company's growth and progress. The insufficiency of cash flow would impede businesses' ability to meet their operational expenditures, hence impeding their normal company operations. In some cases, individuals may find it necessary to get loans in order to cover these expenses." (Benjamin, 2018)

Construction productivity

Gambo and Said (2014: 1052) mention that "construction cost performance is one of the most important criteria of a contractor's success from its inception to completion of any building project and is of serious concern to parties involved in the building construction because it has a direct and indirect effect on construction productivity." There has been little research on the effects of cash flow or late payment on construction productivity.

In a building project, it might be difficult to maintain a consistent productivity rate. It is influenced by numerous internal and external influences. One aspect of the project's cash flow that reflects the company's financial soundness is payment delay. "The project's success depends on the productivity

of the construction crew in terms of maintaining and efficiently utilising the specified time and budget.” (Alawi, 2021: 1347) The work environment, the nature of the project, the project resources, and the project management are some of the elements that reduce the productivity of the construction crew (Florez, Armstrong & Cortissoz 2020; Kaveh & Vazirinia, 2020; Alawi, 2021: 1347). The cash flow of the construction company’s finances may be a controllable factor in productivity. Many of these businesses are building numerous projects, and they depend on the cash flow from one project to pay for the others.

Prompt payment regulations

The concept of controlled payments in South Africa is not new. The Construction Industry Development Regulations of 2004, which were enacted according to the Construction Industry Board Act 38 of 2000, underwent revisions by the Ministry of Public Works in May 2015. The aforementioned amendment proposed the implementation of ‘Prompt Payment Regulations’.

The Prompt Payment Regulations were regarded as a significant and innovative development for the industry, as they aimed to achieve several objectives: eliminate conditional or ‘pay when paid’ clauses in contracts, establish regular progress payments within designated time periods, prohibit the withholding of payment, grant the right to suspend construction activities or performance in cases of non-payment, allow for the imposition of interest on overdue payments, and enforce a requirement for all payments to be made within a specified timeframe. Despite the fact that many people saw the Prompt Payment Regulations as a positive step; the minister confirmed in October 2017 that the draft regulations had been withdrawn. The proposed legislation and the innovative concepts they reflect appear to have been shelved indefinitely.

Furthermore, it is worth noting that several conventional form construction contracts, such as the JBCC and NEC, provide provisions for resolving disputes. However, it is customary within the industry to allow conflicts to persist before resorting to a lengthy and costly process of adjudication or arbitration after the completion of a project. In order to promote equitable and timely payment to contractors throughout the duration of a project, the implementation of a mandatory statutory form of adjudication for the resolution of payment disputes will facilitate the prompt resolution of such issues as they occur.

“The efficacy of the system outlined in the Prompt Payment Regulations is uncertain, especially in the context of state-funded infrastructure projects. This uncertainty arises from the financial constraints faced by state-owned organisations, municipalities, and departments, which may hinder their ability to fulfill their payment responsibilities.” (Hofmeyr, 2021) Despite the need for actions to align South Africa’s payment practices with worldwide best practices. Hence, any potential law must include the extensive fiscal and procurement obligations, while also acknowledging the current circumstances.

Research Methodology and Method

This research used both primary and secondary data, and it was a quantitative study. Quantitative research uses statistical and graphical methods to investigate variables (Saunders, Lewis & Thornhill, 2015:166). The primary technique utilised for gathering information was a survey questionnaire. Positivism was used in this research with a deductive approach. The epistemological stance of the researcher was objectivist (Saunders, Lewis & Thornhill, 2015:155).

An online survey was used to obtain data. The questionnaire consisted of four sections. The demographic information of the respondents, which provides the types of projects the contractor has been involved in, the total experience the contractor has in the construction industry, the respondents’ personal involvement in the firm will be addressed in Section A. Section B gathered data relative to the cash flow problems experienced by building contractors as a result of late payments. Section C addressed the experience of low business growth, while Section D addressed the main causes for late completion of construction projects.

The population for this research consisted of building contractors based in the Eastern Cape Province registered with the East Cape Masters Builders Association (ECMBA). For the purpose of this paper 42 of the questionnaires that were sent to the participants were completed and valid for analysis, thus representing a sample size of 42. Descriptive statistics were used to analyse the collected data. Mean

scores and standard deviations were used to identify the principal feature affecting the ranking views of the respondents. The data received was analysed using Microsoft Excel software.

Research Results and Discussion

Section A: Demographic background

According to the data, 49% of respondents were females, and 51% of the respondents were male. The results also revealed that the majority of respondents were in the range of their 30s to late 40s. It can be deduced that the majority of the respondents were from companies that were established for less than 15 years based on the firm's establishment.

Section B: Cash flow related problems

Table 1 shows the common causes of cash flow related problems in the construction industry. Respondents were requested to rate their responses on a five-point Likert-type response scale for each of the factors listed, where U = unsure, SD (1) = strongly disagree, D (2) = disagree, N (3) = neutral, A (4) = agree, and SA (5) = strongly agree. The range for the mean scores (MSs) are as follows; strongly disagree ($1.00 \leq MS \leq 1.80$), disagree ($1.80 < MS \leq 2.60$), neutral ($2.60 < MS \leq 3.40$), agree ($3.40 < MS \leq 4.20$), strongly agree ($4.20 < MS \leq 5.00$).

Table 1: Cash flow related problems

Ref	Rank	Aspect	Mean
Q11- 1.5	1	Cash flow problems cause financial hardship for the contractor.	4.84
Q11-1.24	2	Cash flow is the lifeblood of a business and can make it or break it.	4.77
Q11- 1.1	3	Late payments cause cash flow problems.	4.73
Q11-1.11	4	Cash flow problems are a significant cause of stress for contractors.	4.68
Q11- 1.3	5	Contractor's cash flow forecast is affected by late payments.	4.61
Q11- 1.6	6	Cash flow problems cause an increase in construction cost.	4.60
Q11-1.28	6	Dealing with late payments is a challenge for contractors.	4.60
Q11-1.30	8	Late payment culture is engrained in the construction industry.	4.57
Q11-1.35	9	Payment culture of the construction industry affects cash flow chain payment work first get paid later.	4.56
Q11-1.26	10	Late payments result in additional borrowing.	4.49
Q11-1.16	11	The contractor's cash flow and financial status depend on the adequate payments from the principals.	4.44
Q11-1.27	11	Late payments result in financial challenges for contractors.	4.44
Q11-1.19	13	Cash flow stability is the key determinant of financial stability.	4.40
Q11-1.18	14	The client's progress payment is a source of a contractor's inflows.	4.36
Q11-1.23	15	Preparation is the key to unlocking a company's cash flow and ensuring that a business is fully maximising its working capital.	4.32
Q11-1.21	16	Cash flow problems occur as a result of ripple effects on an economic downturn.	4.24
Q11-1.32	17	Contractors should evaluate the client's late payments record and make provisions in their working capital calculations for projects.	4.22
Q11- 1.2	18	Contractors experience cash flow difficulties due to delays and non-payment on other projects.	4.20
Q11-1.10	18	Contractor's insufficient financial resources result in cash flow problems.	4.20
Q11-1.14	20	Contractor's lack a plan of building cash reserves results in cash flow issues.	4.17
Q11-1.33	21	Inadequate budgetary control by client affects the contractor's cash flow.	4.16
Q11-1.17	22	The monitoring and control of the progress of the project and the management of the project cash flow identify the benchmarks of the project overruns and delays.	4.15
Q11-1.20	23	Financial market instability causes cash flow problems.	4.07
Q11- 1.9	24	Contractor's delay in submitting claims and causes cash flow problems.	4.00
Q11-1.22	25	Cash flow issues occur due to poor credit control by the contractor.	3.98
Q11-1.29	26	Deficiencies in paymaster's management and capacity influences late payments.	3.97

Q11-1.25	27	Cash flow has a negative impact on the success of a construction company.	3.95
Q11- 1.4	28	Cash flow problems occur due to lack of initial capital.	3.88
Q11-1.15	29	Client's poor financial management causes cash flow problems.	3.84
Q11-1.13	30	Cash flow problems are a result of the contractor's cash flow forecasting.	3.68
Q11-1.31	31	Client does not enforce timely payments.	3.50
Q11- 1.7	32	Cash flow problems occur due to client's poor financial management.	3.44
Q11-1.12	33	Cash flow issues are hard to avoid.	3.32
Q11- 1.8	34	Cash flow problems occur due to client's failure to cultivate good payment attitude among its employees by wrongfully withholding payment.	3.20
Q11- 1.5	35	Client wilfully withholds payment for personal or financial reasons.	2.76

As shown in Table 1, respondents strongly agree that cash flow problems put contractors in a difficult financial position (Ranked 1 with a MS = 4.84), that cash flow is a company's lifeblood and may make it or break it (Ranked 2 with a MS = 4.77) and that cash flow problems are a result of late payments (Ranked 3 with a MS = 4.73). Respondents said that contractors experience a lot of stress as a result of cash flow problems (Ranked 4 with a MS = 4.68). It should be emphasised that respondents strongly agree that late payments have an impact on contractors' cash flow estimates (Ranked 5 with a MS = 4.61). Additionally, respondents agreed that both client's bad financial management (Rank 32 with a MS = 3.20) and cash flow problems are caused by the client's poor financial management (Rank 34 with a MS = 3.44). Furthermore, the respondents stated that the client purposefully withholds payment due to either financial or personal issues (Ranked 35 with a MS = 2.76). Hypothesis 1 stated that building contractors experience cash flow problems due to late payments by clients. As shown in Table 4.1, contractors do occasionally receive late payments from clients. The aforementioned findings provide evidence in support of the hypothesis as most mean scores (MS) is greater than 4.00.

Section C: Low business growth experienced by contractor

The aim of this section (Table 2) was to identify the reasons and impacts of low business growth of contractors. Each of the factors listed below was given a five-point Likert-type response scale where U = unsure, SD (1) = strongly disagree, D (2) = disagree, N (3) = neutral, A (4) = agree, and SA (5) = strongly agree. The range for the mean scores (MSs) are as follows; strongly disagree ($1.00 \leq MS \leq 1.80$), disagree ($1.80 < MS \leq 2.60$), neutral ($2.60 < MS \leq 3.40$), agree ($3.40 < MS \leq 4.20$), strongly agree ($4.20 < MS \leq 5.00$).

Table 2: Low business growth experienced by contractor

Ref	Rank	Aspect	Mean
Q12- 1.3	1	Late payments create negative relationships among parties.	4.79
Q12- 1.7	2	Late payments lead to bad working relationships.	4.63
Q12-1.14	3	Late payments tarnishes the image of contractors.	4.57
Q12-1.31	3	A lower credit score makes obtaining credit facilities in the future harder and more expensive.	4.57
Q12-1.13	5	Late payments has a negative effect on future borrowing.	4.56
Q12- 1.4	6	Late payments negatively affect creditworthiness with financial institutions.	4.55
Q12- 1.5	7	The culture of persistent late payments has a negative effect on business growth.	4.53
Q12- 1.6	7	Late payments choke growth opportunities, leading companies to stagnate.	4.53
Q12-1.35	7	Contractors' relationships and reputations deteriorate, with the effect of compromising finance and creditworthiness.	4.53
Q12-1.34	10	Contractor's inability to pay suppliers on time, impacts their future relationship with suppliers.	4.51
Q12-1.24	11	Economic and market conditions affect/ influence business growth.	4.49
Q12- 1.9	12	Late payments cost an enormous amount of money each year.	4.48
Q12- 1.2	13	Late payments reduce business profitability.	4.47
Q12- 1.8	13	Delayed payments affect business growth.	4.47

Q12-1.19	13	Late payments are toxic to business growth and the sustainability of a business.	4.47
Q12-1.25	16	Weak management practices influence business growth.	4.42
Q12-1.10	17	The issue of the late payments leads to serious repercussions for contractors.	4.40
Q12-1.30	17	Client's late payments to a firm will also have an impact on the business's credit score.	4.40
Q12- 1.1	19	Late payments curtail business growth.	4.38
Q12- 1.26	20	Cash flow constraints of contractors result in business failures and ripple effects down the supply chain.	4.37
Q12-1.23	21	Construction companies collapse because capital is not invested back in the business.	4.35
Q12-1.33	21	Contractors are unable to take on new projects due to insufficient working capital.	4.35
Q12-1.32	21	Contractors experience financial difficulties due to failure to secure contracts.	4.35
Q12-1.12	24	Contractors experience low business growth due to acceptability of late payments.	4.33
Q12-1.15	25	Late payments reduces the contractor's profit margins.	4.33
Q12-1.20	26	Due to late payments, organisations are unable to invest resources in development.	4.30
Q12-1.28	26	Growth in the construction sector can be stimulated by an economically enabling environment.	4.30
Q12-1.11	28	Late payments result in scarcity of capital to finance projects.	4.29
Q12-1.18	29	Late payments are quickly converted into bad debts, which can be extremely detrimental to contractors.	4.26
Q12-1.21	30	Construction companies' growth prospects are seriously compromised by the widespread problem of late payments.	4.25
Q12-1.17	31	Contractors are unable to meet operating expenses due to late payments.	4.23
Q12-1.29	32	The efficiency and soundness of a business are influenced by a client postponing payment.	4.12
Q12-1.27	33	Contractors experience low business growth due to a lack of proper process implementation.	4.10
Q12-1.22	34	Business growth is affected by public sector clients that never pay on time.	3.98
Q12-1.16	35	Late payments does not affect contractors.	1.42

As shown in Table 2, there is an agreement among the respondents that relationship problems arise between parties as a result of late payments (Rank 1 with a MS = 4.79). Late payments create unfavorable working relationships (Rank 2 with a MS = 4.63), and damage the reputation of contractors (Rank 3 with a MS = 4.57). Late payments prevent contractors from taking on new projects due to a lack of working capital (Rank 21 with a MS = 4.35). Furthermore, contractors' inability to pay suppliers on time affects their working relationships with those suppliers in the future (Rank 10 with a MS = 4.51), and as a result, their relationships and reputations suffer, undermining their capacity to obtain financing and maintain creditworthiness (Rank 6 with a MS = 4.55). The respondents vehemently disagreed that contractors are not impacted by late payments (Rank 35 with a MS = 1.42). The survey respondents, as shown in Table 2, concur that late payments have a detrimental impact on future borrowing and that business growth is hindered by public sector clients who never pay on time. As a result, contractors face low business growth. It is almost impossible for contractors to cover operating costs due to the non-availability of funding. In Table 2, the MSs range from $1.42 \leq 4.79$.

Section D: Late completion of projects

The aim of Table 3 was to identify the reasons behind the late completion of construction projects. For each of the factors stated, respondents were asked to rate their views on a five-point Likert-type response scale where U = unsure, SD (1) = strongly disagree, D (2) = disagree, N (3) = neutral, A (4) = agree, and SA (5) = strongly agree. The range for the mean scores (MSs) are as follows; strongly disagree ($1.00 \leq MS \leq 1.80$), disagree ($1.80 < MS \leq 2.60$), neutral ($2.60 < MS \leq 3.40$), agree ($3.40 < MS \leq 4.20$), strongly agree ($4.20 < MS \leq 5.00$).

Table 3: Late completion of projects

Ref	Rank	Aspect	Mean
Q13- 1.2	1	Delay in payment demotivates the workforce.	4.81
Q13-1.13	2	Late payments result in suspension of works on-site.	4.68
Q13-1.24	3	Money is generally the most crucial factor in the completion of projects and is often the number one concern of the contractor.	4.52
Q13- 1.3	4	Late payments distract scheduling of work and the programme.	4.48
Q13- 1.4	5	Late payments restrict productivity.	4.45
Q13- 1.9	6	Late payments often result in an extension of time.	4.44
Q13- 1.8	7	Delay in payments result in difficulties procuring material and equipment.	4.43
Q13-1.11	8	Delay in payment hinders the contractor's labour incentive programme.	4.42
Q13- 1.1	9	Late payments causes delay in the project progress.	4.41
Q13- 1.7	10	Late payments cause conflict and poor communication among the stakeholders involved.	4.39
Q13- 1.6	11	Delays cause cost overruns and contract failure.	4.34
Q13-1.22	12	Late completion of the works due to the contractor's inability to pay wages.	4.33
Q13- 1.5	13	Delays cause disputes over payment and claim responses.	4.32
Q13-1.23	14	Negative cash flow situations affect employee morale which leads reduced productivity levels.	4.25
Q13-1.12	15	Delay in payment affects the contractor's equipment and operation capabilities.	4.20
Q13-1.26	16	The cash flow of the construction company's finances may be a controllable factor in productivity.	4.14
Q13-1.16	17	Late payment which causes suspension of work is not always the fault of the client.	4.14
Q13-1.25	18	Factors affecting the performance and on-site productivity can be grouped into financial or cash flow factors in the construction industry.	4.07
Q13-1.29	18	Project delays occur due to conflict among the parties involved in the projects.	4.07
Q13-1.17	20	Delays are caused by the improper supervision and financial control.	4.00
Q13-1.10	21	Late payments result in low-quality work due to contractors uncertain conditions.	3.98
Q13-1.15	22	Lack of continuity of construction activities and breakdown in the command structure are caused by late payments.	3.88
Q13-1.20	23	Delays are caused by poor contract phrasing, different interpretations of the contractual clauses by government and service providers, and a lack of proper communication to the affected party.	3.79
Q13-1.19	24	Delays are caused by the lack of proper tools and equipment.	3.79
Q13-1.27	24	Delays are caused by disagreements on the valuation of work done.	3.79
Q13-1.21	26	Contractor produces low quality works due to uncertain financial condition.	3.64
Q13-1.28	27	Late completion of projects happen due to delay in certification by the consultant.	3.58
Q13-1.18	28	Construction projects are stalled due to lack of funds on the part of the client.	3.56
Q13-1.14	29	Deferral of payments occur due to design issues	3.21

From the results in Table 3, it can be deemed that respondents concur that late payments demotivate workers (Rank 1 with a MS = 4.81), that not receiving payment on time causes work to be suspended on site (Rank 2 with a MS = 4.68) and are typically the contractors top concern of contractors (Rank 3 with a MS = 4.52). Respondents also agreed that money is typically the most important factor in completing projects. Respondents also agreed that payments are delayed because of design flaws (Rank 29 with a MS = 3.21). The main cause of project completion delays, according to hypothesis 3, is the failure to pay building contractors on time. Table 3 shows that one of the causes of the delayed project completion is unquestionably late payments. The hypothesis is thus supported. With respect to the factors stated in Table 3, mean values greater than 4.00 indicate that respondents tend to agree, while mean values closer to 3.00 suggest that respondents were unsure and those close to 2.00 indicate

that respondents likely disagree. In Table 3 the mean scores range from $<3.21 \leq 4.81$. Thus, hypothesis three is thus supported.

Conclusions

The improper payment methods, such as using contractors' own funds for capital for construction and then claiming, have a severe impact on the construction industry. Long payment processes additionally compel consultants to carefully evaluate contractors' payment claims.

According to the empirical study work delays appear to be widespread in the construction industry. The pay-if-paid system has drawbacks since the contractor cannot always receive full payments as a result of incomplete or defective projects. Any disruption in cash flow can induce a contractor's bankruptcy. Tension between the contractor and other service providers may arise as a result of late payments. Tensions could result in decreased productivity, delays and even worse, more late payments.

Recommendations

The following is recommended for contractors

To avoid a delay in payment approvals, contractors should be advised or mentored from the beginning of the project regarding all the relevant documentation and supporting documents. Recruiting and securing qualified personnel for relevant projects. Contractors should always try to adhere to standards and manage their funds better.

The following is recommended for clients

The government should account for payment delays in budgets as a significant client to the construction industry and offer ongoing professional development for staff members who handle payments; this would guarantee that these staff members remain abreast of changes and comprehend contractors' challenges. The government should make it mandatory for all departments to report on how they handle payments, including how many invoices they pay foregoing the predetermined terms. Service providers will benefit from knowing the departments' payment policies before entering into a contract with them. Develop payment regulations with input from all interested parties and make late payment interest mandatory. The government should promote the adoption of 'good practice' advice among large companies for effectively managing supply chains. This includes the dissemination of performance statistics pertaining to timely payment to contractors, which should be included in audited annual accounts. The government should mandate that inquiries about prior payment performance be included in the disqualifying process for all new government contracts, and the payment history should be taken into account throughout the bidding process. To lower the government's rates of payment delays and to let the industry know when contractors are really at fault, the government should certify all late payments.

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The Impact of Load Shedding on Bulk Water Supply to Metro Municipalities: a Case Study of the Water Sector in Gauteng Province, South Africa

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Abstract

This study investigates the impact of load shedding on the water sector in Gauteng Province, South Africa. Using an inductive, qualitative approach, a case study was conducted to explore the impact of load shedding on a Bulk Water supply organisation. Five (5) respondents from the Operations Department who participated in the study were purposively sampled, and semi-structured interviews were conducted. Ethical considerations, including consent and confidentiality, were ensured. The analysis identified key themes from the data, offering insights into operational challenges and social dynamics related to water supply management during power disruptions. It was found that water extraction is relatively resilient, and secondary and tertiary stations face significant challenges due to reliance on electricity. Manual interventions and backup generators introduce inefficiencies and additional costs. Socio-economic impacts are notable, particularly for Tertiary stations and low-income communities. Effective mitigation requires robust infrastructure, comprehensive protection frameworks, and exploration of alternative energy sources. The study focused on the Gauteng province impact of load shedding in the water sector, specifically focusing on bulk water distribution from extraction at the Vaal dam and distribution to the Reservoirs of respective Metro Municipalities. The study provides awareness of challenges caused by power disruptions in the water sector and further enhances the interdependencies between water and power supply. This study offers insights for Bulk Water Stakeholders on mitigating load-shedding impacts through renewable energy solutions and influencing integrated energy-water policy development at the national level.

Keywords: Load shedding, Bulk Water Supply, Infrastructure, Operations, Eskom.

Introduction

The Electricity Supply Commission (ESCOM) of South Africa (SA), which was founded in 1923, is mandated to supply electricity to the nation's residents efficiently, effectively, and sustainably in terms of the Electricity Act No. 42 of 1992 ("Electricity Regulation Act 4 of 2006 | South African Government" 2006). Sustainable water management addresses the needs of billions lacking safe drinking water and sanitation (United Nations 2023). Energy is essential for powering water technologies and infrastructures, ensuring the supply, distribution, and delivery of water services, and supporting efforts to enhance or rehabilitate water quality (Mayor, Casado, Landeta, López-Gunn & Villarroya 2016). Water and energy are intricately connected, with water being essential at every phase of the energy supply chain, and energy being vital for processes like extraction, distribution, treatment, and desalination of water (Terrapon-Pfaff, Fink & Lechtenböhmer 2018). Economic development and social well-being are fundamentally dependent on the energy and water supply industry (Kılıç 2020: Kostić, Vučić & Majstorović 2018). The safety of each resource is linked to the security of the other resources, as seen drinking water affects utilisation of food security, reliance on energy resources for cooking, and use of water as a cooling system to produce electricity (Ding, Gunda & Hornberger 2019). This is also supported by Madolo, Telukdarie and Kumar, (2018), who emphasise that electricity is a vital component since coal power plants in South Africa use wet cooling systems to generate electricity, the country's water utilities must use more energy to pump water.

There is a direct relationship between electricity and water supply because water supply shortages due to electricity outages can have devastating social and economic effects on highly populated urban areas (Pappis et al. 2020). Africa's doubled GDP since 2000, growing at 5% from 2008 to 2015, is hampered

by challenges in the electricity network, disrupting power supply for major cities (Cole, Elliott, Occhiali & Strobl 2018). Since the 1980s, the world's water demand has been increasing by 1% annually, and it is predicted to continue until 2050 (Ramos, Morillo, Diaz, Carravetta & McNabola 2021). Urbanisation and middle class growth has an impact on the consumption of water, food, and energy resources (Monsef, Naghashzadegan, Farmani & Jamali 2018).

The major functions of a country or human habitations are likely to suffer as a result of insufficient service delivery, and there could be a further increase in electricity and water scarcity due to inadequate infrastructure, among other problems (Aiyetan & Das 2021). The water operations are disturbed to varying degrees in the case of a power outage depending on the characteristics of the plant and the availability of backup power. Since more and more customers have been connecting to the national grid in the past few years, Eskom is having trouble keeping up with an adequate supply of electricity (Flepisi & Mlambo 2021). Ateba et al., (2019) indicated that companies are using significant amounts of electrification to generate power for all production-related technologies, which has led to a rapid advancement in the use of electricity in industry worldwide. Macharia, Kreuzinger and Kitaka, (2020) states that as far as the authors know and understand, there isn't a lot of research or case studies on how the Water-Energy Nexus concept and its factors that affect water supply in utilities in Africa are being used.

Declaration of the national state of disaster

On the 27 February 2023, The laws implementing the National State of Disaster regarding the effects of Severe Electricity Supply Constraints were published in the South African government's gazette (South African Government 2023). The declaration of a disaster would make it possible to implement the necessary practical steps, such as the installation of generators and solar panels to assist in an uninterrupted power supply. When technically possible, it would allow for the exemption of critical infrastructure from load shedding, such as hospitals and water treatment facilities. This serves as a substantiation that the problem of power supply started several years as far back as 2007.

The problem is that South Africa has been experiencing a consistent implementation of electricity load shedding more often than the previous years and that has impacted several industries, particularly the water sector's day to day operations in the case of Bulk Water supply, leading to water supply interruptions to various Metro Municipalities of Gauteng. There are also limited studies done on the effects of power disruptions in the South African water sector. The extent of power outages in Africa is poorly documented and a regional assessment by (Nduhuura, Zerga & Garschagen 2018) using World Bank enterprise survey data from 2010 to 2017 revealed significant regional variations.

The objective of the study is to explore the impacts of load shedding in bulk water supply to Metro Municipalities: Case of the Water Sector in Gauteng province, South Africa by undertaking the following:

- Investigating how load shedding disrupts Bulk Water's daily operations in water treatment and distribution to the Metro Municipality, with a focus on identifying specific challenges and bottlenecks.
- Evaluate the effects of load shedding on pumping efficiency and the quality of water supply during and after load shedding periods, aiming to quantify any observable changes and potential risks.
- Determine the extent to which load shedding affects the entire value chain of bulk water supply, exploring disruptions from water sourcing to distribution, to provide a comprehensive understanding of the impact.
- Discover the measures and strategies implemented by Bulk Water to minimise the impact of load shedding on its operations, assessing the effectiveness of these measures in maintaining a consistent and reliable water supply to the Metro Municipality.

The study will inform other professionals and specifically the Bulk Water Stakeholders of the interdependency of energy and water, thereby opening a discussion on how to explore the use of renewable energy and other alternatives to mitigate negative impacts of load shedding in water supply. This can also influence the integration of energy and water policies as well as frameworks at National level which can be adopted by other spheres of government. The study will create awareness and highlight the consequences of the issue of load shedding in the water sector.

Literature Review

A global analysis of the effects of power interruption in the water sector

The water-energy nexus concept has gained popularity over the past few years, sparking scholarly publications and international events (Fayiah et al., 2020). Pourmaras et al. (2020) used a modular simulation approach to study how power network failures impact water supply shortages, finding that urban water systems heavily depend on stable power networks. Adepu et al., (2020) adds that disrupting the power supply to a single high-rise residential building could result in various issues for occupants, such as the absence of water supply (as the overhead water pump requires electricity) and communication failures.

In the United States (U.S), about 322 billion gallons (1219 billion Megalitres) of water are withdrawn for use each day, among which about 34% withdrawals are for thermoelectric power and 14% for public supply and about 80% of the total energy consumption comes from fossil fuels and about 4% of the nation's electricity generation is water related (Dieter et al. 2018).

Melaku, Fares and Awal, (2023) discovered very cold and severe winter storm Uri that hit Texas in February 2021, caused power outage, water systems failures and air quality issues. Collected Data from February 2021 and June 2021 showed the impact of freezing temperatures in these systems. Temperature data was obtained from PRISM climate analysis system (Daly et al. 2008), while water quality and air quality indicators came from the Texas Commission of Environmental Quality (TCEQ). Air quality index (AQI) was used as a scale that shows how polluted the air is and its impact on health. The findings show that extreme weather led to significant temperature fluctuations, resulting in power outages, failures in the water system, and the release of pollutants. Bolinger et al. (2022) evaluated the South-Central U.S. Arctic outbreak and found that Winter storm Uri in February 2021 caused pipes to freeze and burst, leading to water pressure loss and 43% of Texas' community water systems, issuing boil water notices ("After-Action Review of Public Water Systems and Winter Storm Uri" 2022) due to lack of preparedness for such events. Castellanos et al. (2023) similarly found that freezing temperatures and electrical grid failures revealed existing vulnerabilities and fragility of water service provision leading to inadequate water treatment and the potential contaminants in the water supply. Glazer et al., (2021) suggest that State-level policies enforce identification and prioritisation of vital infrastructure, coupled with mandated backup power could have averted numerous preventable water-related disruptions.

Lee, Maron and Mostafavi, (2022) assessed the unequal impacts of managed power outages, burst pipes, and food access issues during the 2021 winter storm in Texas, using community-scale data from January and February 2021. Data was collected through Population activity, 311 service helpline, Point of Interest Visit data and Demography data. The study found potential inequalities in power outage management, with more frequent 311 calls from low-income and racial minority groups, indicating greater challenges for these communities. The research highlights the importance of community-scale data for rapid impact assessment during extreme weather events and offers insights for improving social equity in infrastructure management.

Hurricanes and winter storms have caused significant failures of the electric power grid. Hurricane Maria in Puerto Rico disrupted over 4.0 billion customer hours, making it the second-largest power outage in history (Marsters & Houser 2017). The Sendai Framework for Disaster Risk Reduction 2015-2030 aims to strengthen communities by understanding the connections between essential facilities and the consequences of their failures (Omitaomu & Kar 2018). Discussions on Hurricane Maria's impact highlighted the extensive damage to electricity infrastructure, leaving people without power and clean water for extended periods (Joseph, Voyles, Williams, Smith & Chilton 2020). A study on the interactions of Hurricane Maria and the 2020 earthquake series utilised multiple data collection methods including survey to assess the extent of damage, using various types of images, capturing pictures and videos using a drone and using Lidar scan data (Hain, Zaghi, Padgett & Tafur 2023). It also referenced a report by (van der Elst, Hardebeck & Michael 2020) that observed aftershocks of the hurricane up to 17 January 2020, and used a statistical model to estimate the duration.

Water and energy relationship in Africa

Africa occupies 15% of the Earth's and is home to 13% of the global population, consumes only 3% of the world's electricity and contributes only 2% to the worldwide industrial capacity. Africa's power generation capacity is about 105,000MW (Davidson 2005). Over the last 60 years, Sub-Saharan African countries have built dams and used hydropower turbines to generate electricity, but this infrastructure is insufficient for the growing population (Ijoma et al. 2022). Insufficient electricity access impedes water pumping, especially during dry periods, disrupting agriculture and drinking water availability (Pappis et al., 2019). European Commission. Joint Research Centre. (2020) analysed the Southern African Power Pool (SAPP) for 2016-17, using synthetic hourly load profiles and a regression approach to align energy demand balances with 2017 data. The study found that increased water availability in the SAPP can reduce the negative economic impacts of unserved electricity, lowering prices and improving economic activity. Pavičević et al. (2021) noted that system adequacy is lacking in several countries, causing significant load shedding. Enhancing interconnection capacities could nearly eliminate load shedding. However, the demand for resources driven by human needs strains their availability (Ifelebuegu & Ojo 2019).

To address gaps in empirical literature, Nduhuura, Garschagen and Zerga, (2021) analysed the effects of electricity outages on urban households in Accra, Ghana, using 564 surveys from September to November 2018. They found that electricity is crucial for water supply systems, making them vulnerable to disruptions during outages, although socio-economically disadvantaged individuals might be less affected due to their usual lack of access to piped water. Kayaga *et al.*, (2021) studied the effects of flooding and extreme heat on water and electricity services in Accra and Tamale, Ghana, using 124 interviews, water quality analysis, and household interviews. The study revealed the interdependence of water and electricity services, highlighting how challenges in one sector exacerbate issues in the other. Eledi Kuusaana, Monstadt & Smith (2023) examined how electricity supports activities and the effects of power interruptions in Accra, Ghana, through interviews and observations of urban residents and business managers across various income areas. The study, including data from 2018, 2019, and 2022, found diverse levels of exposure, sensitivity, and adaptation to blackouts, underscoring socio-economic and spatial disparities in electricity access. A facilities manager noted that luxury apartment residents rely entirely on electricity, making outages particularly inconvenient for essential activities like water pressure, cooking, and using the washroom.

Zambia Electricity Supply Corporation (ZESCO) is the national electricity utility and according to the (National Energy Policy 2019) Zambia has a total installed generation capacity of 2,976.3 MW. The policy further elaborates that this capacity is composed of different energy sources such as hydro contributes 80.8%, coal contributes 10%, heavy fuel oil contributes 3.5%, diesel contributes 2.7%, and solar PV contributes 3% as of September 2019.

The Zambian government is enhancing renewable energy in its energy mix. However, the 2015/2016 drought reduced water levels in key rivers, causing significant drops in hydroelectric power generation and resulting in up to 8 hours of load shedding affecting homes and industries (Mainza & Ziba 2020). Umar and Kunda-Wamuwi, (2019) studied the impact of power outages in Lusaka on residents and SMEs in August 2015 and February 2016, the study involved 200 households from Ng'ombe and Kalingalinga, and 14 small businesses. Findings showed that load shedding disrupts water supply for households relying on municipal piped water, often forcing women to fetch water from other sources, increasing their workload. Another study by Bwalya Umar *et al.*, (2022) investigated load shedding impacts on 510 households in Kitwe, using mixed methods in April 2016, the study found that over 50 respondents in both low and high-income areas reported connections between load shedding and water supply disruptions, as power outages affect water reservoirs' ability to supply water to nearby regions.

Load shedding and water supply effects in the South African context

In South Africa, access to electricity and basic services like housing, education, and water is closely linked to significant poverty and socio-economic inequality (Baker & Phillips 2019). Amid slow economic growth, consumer pessimism is increasing, exacerbated by the impact of load shedding (Fitch Solutions 2023). Despite assurances from former Deputy Director-General Trevor Balzer that no water disruptions were reported due to load shedding ("DWS working to secure water supply amid load shedding | Infrastructure news" 2019), Magalies Water, (2019) report identified unreliable power supply as a major factor hindering bulk water infrastructure from meeting demand. Studies show a complex relationship

between electricity use and water supply. From 1991 to 2021, South Africa's electricity demand increased, but Eskom built only one power plant, accumulating significant debt due to fraud and mismanagement, hindering infrastructure investment (PLE, 2023). Gehringer, Rode and Schomaker, (2018) define load shedding as recurring brief power outages implemented by Eskom to prevent uncontrolled blackouts.

Basic water supply, as defined by The Presidency, (2005), ensures households have enough clean water for living and hygiene. The efficiency of water transportation is heavily influenced by the condition of vast, interconnected water distribution networks (Mosetlhe, Hamam, Du & Monacelli 2020). Rand Water, Africa's largest bulk water utility, provides clean water to over 11 million people in South Africa across Gauteng, parts of Mpumalanga, the Free State, and North West, covering over 18,000 km². Bulk water pumping stations are as shown on the Table 1 below, pumping stations rely on electricity from Eskom and local municipalities (Makhathini 2019) to distribute water.

Table 1. Rand Water Electricity supplied pumping stations (Makhathini 2019)

Electricity Supplier	Primary Pumping Station	Tertiary Smaller Pumping Station
Eskom	Zuikerbosch, Zwartkopjes, Palmiet	Daleside, Libanon, Lethabo, Trichardt, Bloemendal, Mamelodi, Cullinan, Townlands, Ironside, Zuurbekom
Emfuleni	Vereeniging	Houtkop
City of Johannesburg	Eikenhof	Roodepoort
Ekurhuleni	Mapleton	-
Metsimaholo	-	Sasolburg

Winter, (2011) investigated the effects and results of power outages on water and wastewater treatment services. Primary data was collected by using telephone or face to face interviews and secondary data was gathered from published and online material. The respondents were selected in accordance to organisational type, Targeted designation, and the type of information required.

Winter's study highlights that in 2007, Rand Water used about 1.7 billion kWh of electricity, averaging 662 kWh per Megalitre of treated water. The analysis, focused on Johannesburg Water and Magalies Water from 2007 to 2008, found that load shedding caused production losses to major customers like mines and water quality deterioration after 2 hours, worsening with prolonged outages. (Haes Alhelou, Hamedani-Golshan, Njenda & Siano 2019) reviewed 136 unique papers on significant blackouts from 2001 to 2018, finding that facilities in large cities and towns rely on electricity for water treatment and pumping, posing serious health risks like disease outbreaks during outages. This aligns with Bhagwan (2020) view that most water supply in Gauteng and nearby provinces depends on pumping systems, which stop working during prolonged power outages.

The consequential risks and mitigation measures associated with load shedding in the South African water sector (Gauteng Province)

The Rand Water 2021/2022 report highlights concerns about Eskom's reliability as its primary electricity provider, which impacts water pumping operations (Rand Water 2022) . Potgieter *et al.*, (2019b) conducted a case study in Tshwane, finding existing agreements between electricity suppliers and water authorities inadequate. They proposed the Risk Analysis Mitigation Framework for Integrated Water and Electricity Systems (RAMFIWES) to address electricity disruptions' effects on water supply. The study indicated that reducing water supply interruptions has a high benefit-to-cost ratio of over 15% and would increase potable water costs by only 0.5%. Joshi & Mohagheghi (2021) examined the impact of power outages on water treatment plants and suggested an operational plan for an isolated microgrid on an island.

Paladh, Baloyi, Holder & Knox (2021) analysed the water-to-energy market in South Africa, noting that Rand Water Board is part of the Energy Intensive Users Group of Southern Africa (EIUG). They concluded that hydropower, defined as power derived from moving water (Ellabban, Abu-Rub & Blaabjerg 2014), has sustainable potential for municipal, water board, and mining use. Data from the US Department of Energy and U.S. Geological Survey and the results from the (National Energy Policy 2019) supports that this approach could enhance community resilience by providing reliable electricity and clean water during and after disasters.

Research Methodology and Method

A case study was adopted to enable distinct illustration and analyse participant's experiences. And in this case, it involved an in-depth exploration of the Bulk Water supply organisation into the complexities of the impact of load shedding in water supply. An inductive approach was employed for the thorough examination of unprocessed collected data to extract concepts, identify themes, and develop models based on the interpretations of the raw data (Jebreen 2012). Given the nature of the research problem, a qualitative strategy was chosen to grasp the overall context, roles, interpretations, and status of the phenomena under investigation (Pulla & Carter 2018). This strategy does not only reveal lesser-explored social processes within specific groups but also facilitates the development of new methodologies, the re-evaluation of existing literature, and the formation of fresh concepts and categories throughout the research process (Sánchez et al. 2022).

A population of respondents was selected from the bulk water distribution (Operations Department) (Sekaran & Bougie 2016) targeting Maintenance Manager, Executive Manager, Regional Manager and Superintendents. Purposive sampling was adopted to specifically select respondents working within the Bulk water distribution, possessing specific characteristics and have relevant information to the study (Turner, 2020). Semi-structured interviews were conducted probe into the interviewee's subjective perspective, but this does not imply unquestioning acceptance of their statements without critical examination (Wengraf 2001). Prior the interview, Consent was obtained from the respondents as part of the preparation (Gudkova, 2018). A data collection protocol was developed containing the following domains, basic information about the interview, introduction, opening question, content questions, use of probes (depending on the response of the respondent) and closing instructions (Creswell & Creswell 2018). Ethical considerations for the study were approved through the Ethics Committee to ensure privacy for interviews conducted in a digital platform. Confidentiality is an ethical risk considered to ensure that any sensitive information shared during the online interview remains confidential and stored securely e.g. video recordings of the interview (Brigham & Kharbach 2020). Five (5) responses were obtained from 1 Maintenance manager, 1 Executive Manager, 1 Regional Manager and 2 District Superintendents. Inductive data analysis was used to navigate through existing literature, arranging data from interviews and crafting meaning from emerging concepts (Thomas 2006) (Weligodapola & Darabi 2018).

It should be noted that the different groups sampled provided similar information and that led to Saturation. Saturation means that no additional information was found to develop properties of a category (Glaser & Strauss 2017).

Research Results

Five (5) respondents participated in the study as per the figure below.

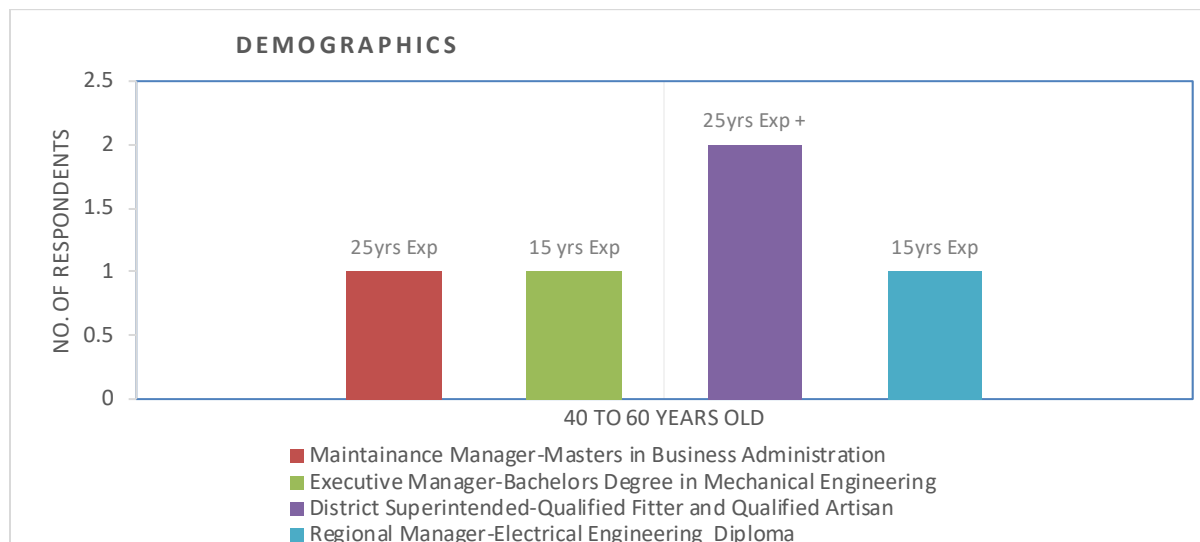


Figure 1: Demographics of respondents

Figure 1 above shows that Five (5) participants responded ranging from 1(20%) Maintenance manager, 1 (20%) Executive Manager, 1(20%) Regional Manager and 2 (40%) District Superintended. Due to the busy schedule of the respondents some preferred conducting the interviews after working hours through teams meeting as intended initially. The demographic analysis of the participants' education and work experience show that 20% hold a Master's degree, 20% hold a Bachelor's degree, 20% a National Diploma while a 40% portion has higher qualifications. There are no participants with Honours or PhD degrees. In terms of work experience, no participants have less than 10 years of experience. A significant proportion (60%) has over 25 years of experience, while 40% have 15-20 years of experience in the bulk water distribution. This indicates that the participants are highly experienced professionals, with most holding advanced technical educational qualifications.

The participant group consisted of 40% females and 60% males, indicating a slight gender imbalance favoring males. In terms of age distribution, all participants are between 40 and 59 years old, with 60% in the 40-49 age range and 40% in the 50-59 age range. This suggesting that the study primarily involved middle-aged individuals.

Interview responses

Table 2: Key themes & summary of responses for the impact of load shedding in bulk water supply:

Key Themes	Summary of Findings or Results
Impact on Water Extraction, treatment and distribution	Disrupts operations, particularly affecting water supply pressure at pumping stations Automated systems for monitoring compromised, requiring manual checks. Time-consuming switching between power sources Recovery time for water systems extensive (up to two weeks). Increased employee fatigue due to manual checks and switching power sources. Infrastructure designed for smaller populations struggles with current demand.
Pumping Efficiency and Water Quality	Water quality remains unaffected as regular checks ensure water quality remains compliant. Load shedding affects pump availability and efficiency due to power trips during load shedding in exempted stations. Pumping stations face challenges using generators at full capacity. Increased workload and frequent call-outs lead to employee exhaustion and reduced efficiency.
Infrastructure Resilience, Increased Maintenance, running Costs	Infrastructure resilient Frequent equipment start-ups and shut-downs risk increased maintenance costs. High diesel costs for generators (300 liters per hour). Increased operational expenses due to overtime.
Mitigation Measures	Use of Generators as backup power. Exemption at Primary and Secondary Stations

Discussion

Challenges

Water extraction from the Vaal Dam, largely gravity-driven, is resilient to power disruptions. Primary treatment plants are exempt from load shedding, ensuring continuous water purification, while tertiary stations, more reliant on electricity, face vulnerabilities, using backup generators to mitigate power outages. These stations suffer from operational delays and reduced efficiency due to manual oversight and the challenges of generator operation. This contrasts with Castellanos et al. (2023), who found that grid failures during a winter storm caused power losses at water treatment plants, leading to inadequate treatment and potential contamination, posing health risks.

Load shedding also disrupts automated systems for monitoring reservoirs and pumps, increasing the risk of human error. Additionally, power cuts reduce water pressure in tertiary stations, leading to supply inconsistencies and increased consumer demand. While infrastructure strain leads to inefficiencies, water quality remains unaffected due to rigorous monitoring. This is consistent with the findings in a study by (Adepu et al. 2020) where he adds that disrupting the power supply could result in communication failures. After a period of load shedding, the system can take time to recover.

Switching to generators requires manual intervention by electricians, adding to the operational delays. The process of switching between power sources and restarting pumps takes considerable time, often leading to reduced water supply and inadequate water pressure during these periods. This is similar to the findings of Eledi Kuusaana, Monstadt & Smith(2023) which confirmed an issue from power disruptions directly impacts water supply pressures.

Mitigation measures

The findings also highlights various mitigation strategies, including securing exemptions, using backup generators, and exploring alternative energy sources like hydropower. Despite some successes, challenges persist, particularly for tertiary stations. More robust and adaptable solutions are necessary to enhance system resilience and maintain a stable water supply during load shedding. Despite the operational challenges posed by load shedding, the quality of water has not been compromised. Regular sampling and monitoring ensure that the water quality remains compliant to the required standards for consumption. This is contrary to the findings by Winter (2011) which indicated that load shedding cause water quality deterioration.

Conclusion

The management of water supply systems during load shedding reveals critical vulnerabilities, especially at Secondary and Tertiary stations reliant on electricity. While initial stages of extraction and treatment show resilience, power disruptions at Tertiary stations reduce efficiency, increase strain, and lead to water pressure issues. Backup generators offer temporary relief but raise operational costs and prolong recovery times. These challenges may disproportionately affect low-income communities supplied by Municipalities, worsening water access and increasing household burdens.

Addressing these issues requires infrastructure upgrades, better backup systems, and maintenance improvements. Critical infrastructure exemptions from load shedding and comprehensive risk management are key to mitigating disruptions. Exploring alternative energy sources like hydropower could enhance reliability but demands careful consideration of feasibility. Ongoing research and investment are vital to adapting water systems to power outages, ensuring public health and socio-economic stability.

Recommendations

Developing more resilient and advanced monitoring systems that can operate during power outages would help maintain operational efficiency and water quality. Upgrading and expanding the existing infrastructure to meet current and future demand is crucial. This includes increasing storage capacities and modernising the distribution network. Investing in renewable energy sources, such as solar power, could provide a more sustainable and reliable backup power solution compared to diesel generators. Establishing better agreements with Eskom to ensure that critical infrastructure is exempt from load shedding or has priority for power restoration could help mitigate the impacts. It is recommended that further studies on the reliance of renewable energy resources be conducted to ascertain sustainability in the South African context.

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The Impact of Quantity Surveyors in Projects Execution Among Small and Medium-sized Contractors in Namibia's Private Sector

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Abstract

This research paper aimed to assess the impact of quantity surveyors (QSs) on Small and Medium-sized Contractors (SMCs) projects in Namibia's private sector. Considering a myriad of challenges facing SMCs, the interventions of construction professionals like Quantity Surveyors (QSs) is undisputably pivotal. The study utilised a questionnaire survey to collect data from sixty-nine conveniently selected respondents comprising registered professional QSs and SMCs. The response rate was 64% and acceptable. The data was analysed by computing mean scores (MSs) and their ranking. The range of interpreting the 5-point Likert scale mean score was given as follows: MSs > 1.00 ≤ 1.79 (Very low contribution/impact), MSs > 1.80 ≤ 2.59 (Low contribution/impact), MSs > 2.60 ≤ 3.39 (Moderate), MSs > 3.40 ≤ 4.19 (High contribution/impact) and MSs > 4.20 ≤ 5.00 (Very high contribution/impact). While the study found that QSs render key services to SMCs, such as cost estimation, project cost control, procurement of materials, and identification of financial and contractual risks, most SMCs in Namibia cannot afford the services of QSs due to financial constraints. Hence, the involvement of QSs on SMCs' private sector projects needs improvement. The small sample size and mono-method quantitative approach preclude the findings from being generalised. Hence, future research could adopt a mixed method approach and a larger sample size to improve data validity. Clients, SMCs and QSs could utilise the results to develop mechanisms entailing collaboration for effective project delivery in Namibia's private sector. There are limited studies on the subject matter within the Namibian context. Therefore, this groundbreaking study would enhance the participation of QSs on SMCs' private sector projects, consequently improving project delivery to private sector clients.

Keywords: Small and Medium-sized Contractors, Private Sector Projects, Quantity Surveyors, Namibia.

Introduction

Small and Medium-sized Contractors (SMCs) are key drivers of infrastructure development in most developing countries (Dhlwayo, Musonda, Gumbo & Kaisara, 2024). Extant literature reveals that SMCs contribute between 50 to 60% to the gross domestic product of nations (Dhlwayo, Musonda & Gumbo, 2022a; Anugwo & Shakantu, 2020). Due to their predominance in the construction industry, the Organisation for Economic Cooperation and Development (OECD) (2019) argues that SMCs are strategic in catalysing infrastructure development in both public and private sectors.

Despite the ubiquity of SMCs in the construction industry worldwide, their performance in successfully delivering projects, particularly in the private sector, has remained appalling due to a myriad of challenges which include poor financial management and technical ineptness (Dhlwayo, Musonda & Gumbo, 2023; Wentzel, Fapohunda & Haldewang, 2022; Bikitsha & Amoah, 2022). This lack of pertinent skills among SMCs appears to epitomise the status quo of most developing countries in Southern Africa. For instance, in South Africa, a plethora of studies (Hove, 2016; Dapaah, Thwala & Musonda, 2017; Wentzel, Fapohunda & Haldewang, 2022) confirm that the absence of critical skills among SMCs retards project delivery, which largely culminates in the discontinuity of most SMC businesses. In fact, Wentzel, Fapohunda and Haldewang (2022) posit that 80% of the SMCs in South Africa shut their business within five years of their inception. Similarly, in Namibia, Mukata and

Swanepoel (2017) observed that 12% of the SMCs close their businesses yearly. This high failure rate within the Namibian context has been attributed to SMCs' lack of technical skills, financial management skills, contract management skills, project management skills, marketing strategies, cost estimation and tendering skills, and technological skills, which are a recipe for effective project delivery (Dhliwayo, Musonda and Gumbo, 2022b).

Although the failure rate of SMCs seems to prevail in both public and private sectors, Dapaah, Thwala and Musonda (2017) demonstrate that some SMCs that obtained work within the public sector over the past decade, registered remarkable performance due to government support and the supervisory role of the government-appointed consultants. Hence, SMCs working in the private sector experience a dire situation which needs some interventions for them to improve project delivery. In the recent past, there has been a clarion call for relevant stakeholders like consultants to intervene to catalyse SMCs' project delivery (OECD, 2019). Several scholars opine that consultants like Quantity Surveyors (QSs) pose a positive influence on SMCs' project success due to QSs' expertise in financial and contractual matters (Esterhuysen & Wood, 2021; Chimonso & Modupe, 2017). This is corroborated by Besklubova and Zhang (2019) who contend that QSs are prominent in advancing the sustainability agenda of the construction industry.

Admittedly, the public sector operates differently from the private sector due to disparate clients, standard forms of contracts utilised, and financing mechanisms employed. While the influence of QSs has been widely noted on projects undertaken by SMCs within the public sector (Dhliwayo, Musonda, Gumbo & Kaisara, 2024; Munaka, Moyo & Dhliwayo, 2023; Dapaah, Thwala & Musonda, 2017), there is paucity of literature regarding the impact of QSs on the projects undertaken by SMCs in the private sector. Considering that SMCs are the main players in the private sector, it is critical that consultants like QSs be proactive in supporting these firms towards effective project delivery within this sector. The current study therefore assesses the impact of QSs in the delivery of SMCs' projects in Namibia's private sector. The study probed two questions: (1) What is the level of QSs' contributions towards SMCs' private sector projects? (2) What is the impact of QSs in the delivery of SMCs' private sector projects? The findings of this study potentially influence SMCs and QSs to develop mechanisms that strengthens their collaboration for effective project delivery in the private sector in Namibia and similar contexts. If consultants like QSs are reluctant in supporting SMCs in the private sector, the success of these entities in delivering projects would remain marginal. Thus, the succeeding sections start by highlighting existing literature the key roles of QSs in project delivery and their influence on SMCs' private sector projects, then followed by the methodological approach employed, research results, discussion, conclusion and recommendations.

Literature Review

Small and medium-sized Contractors (SMCs) in Namibia

SMCs in Namibia experience numerous challenges which impede the effective delivery of their projects (Dhliwayo, Musonda & Gumbo, 2022a; 2022b). Chief among these challenges include unregulated business environment, poor financial management skills and inept technical skills (Dhliwayo, Musonda & Gumbo, 2022b). In a study focusing on SMCs taxonomy, Dhliwayo, Musonda & Gumbo (2023b) found that the Namibian context lacks the legal and regulatory framework to guide the grading or classification of contractors for effective SMC development, unlike its counterparts like South Africa (Dapaah, Thwala & Musonda, 2017) and Botswana (Gasa, 2012) which systematically grade their SMCs. At the national policy level in Namibia, Small and Medium-Sized Enterprises (SMEs) are generically defined without considering peculiarities in different sectors like SMEs in the construction industry (National Policy on Micro, Small and Medium Enterprises in Namibia, 2016). As noted by Dhliwayo (2013) in his doctorate studies focusing on a framework for catalysing development and sustainability of small medium-sized contractors in Namibia, the construction industry is complex relative to other industries, hence SMEs in this sector should be classified based on their capacity and capability to enable the interventions for their proper development and sustainability. As such, it is reported that the current situation adversely affect sustainable procurement of work since majority of SMCs in Namibia often compete for projects which are beyond their capability to successfully execute, and consequently suffer dismal performance, sequestration or closure of their businesses within a few years after inception (Dhliwayo, Musonda & Gumbo, 2023b; Mukata & Swanepoel, 2017). Therefore, in a recent study, Dhliwayo, Musonda, Gumbo and Kaisara (2024) who assessed the critical success factors for the sustainability development of SMCs in Namibia, found that the intervention of consultants

like QSs, particularly in upskilling SMCs, is cardinal to improve the performance of SMCs in the construction industry.

Key roles of quantity surveyors in project delivery

Quantity Surveyors (QSs) are among the key professionals operating in the built environment for the realisation of projects delivery (Aarseth, Ahola, Aaltonen, Okland & Anderson, 2017). Primarily, QSs ensure that projects are completed within schedule, budget, quality and scope (Wao & Flood, 2016). Unlike their counterparts, QSs possess multidisciplinary skills which make them instrumental in championing the success of SMCs. Onunoyoswe (2013) outlines sixteen (16) services that QSs offer in the project delivery process which include preparation of Bill of Quantities, preparing and settling final accounts, cost planning, cost auditing and monitoring, project planning, advising on the selection of other consultants, preparing tender documents, obtaining or negotiating tenders, reporting on received tenders or package deal/design and build proposals, evaluating construction works, periodic financial reporting, technical auditing, assessing replacement value for insurance, project management-related services, giving expert evidence in arbitration and evaluating construction contract claims. Although these services are generally applicable to various contexts, contextual differences result in some services being predominant in one setting relative to the other. For example, in South Africa, Smith (2017) claims that QSs are mainly involved in cost estimation, budgeting, cost management during project execution, monitoring contractual compliance, variance management and dispute resolution. In Zimbabwe, Munaka, Moyo and Dhliwayo (2023) found that QSs are chiefly involved in value management, in which they attempt to attain the lowest possible whole life cycle costs of projects. Additionally, Munaka, Moyo and Dhliwayo (2023) claim that QSs are instrumental in advancing sustainable construction practices, arguing that the mentioned practices are inextricably linked to the value management concept.

Within the Namibian context, the public sector categorises QS functions into four clusters namely estimating and cost advice, documentation, contract administration and preparation of final account (Government Gazette of the Republic of Namibia, 1998, Notice no.250, dated 6 October). It noteworthy to highlight that, based on the four core functions outlined in the government gazette, QSs are expected to perform eighteen (18) roles which include estimating building cost, construction cashflow budgets, design criteria advice, preparation of procurement documentation, preparation of schedule of rates, calling for tenders and evaluating tenders, cost management and reporting, preparation of payment certificates, settling contractual and financial disputes, compilation and settlement of final account, quality inspection, acting as project manager, acting as principal agent, time management, project administration, acting as construction manager, client and consultant coordination and assisting in setting up creative financing schemes. Additionally, the Gazette highlights that QSs could act as arbitrators, expert witnesses or mediators during dispute resolution processes. In recent studies, Dhliwayo, Musonda and Gumbo (2022a; 2022b; 2023a) and Dhliwayo, Musonda, Gumbo and Kaisara (2024) reveal that QSs are key players in promoting the sustainability of SMCs within the Namibian context, through financial advice, cost estimation and tendering of works. These numerous roles confirm the importance of QSs in the industry and the potential they possess in transforming the performance of SMCs in the private sector.

Quantity surveyors' contributions in SMCs' private sector projects

The contribution of QSs towards SMCs' success is scantily profiled by scholars. However, Hiew and Ngao (2010) claim that QSs' diversified skill set could assist owner-managers of SMCs in making wise decisions on financial and contractual matters. According to these authors, pertinent skills advanced by QSs on construction sites include purchasing decisions which entails having current market information and pricing skills, production network examination and determination, and critical preparation and purchasing abilities. As noted by Mackie and Cooper (2012), QSs proactively manage the budget provided by the project owner to attain best value for the money spent on the construction project. In addition, Dwivedi and Dwivedi (2021) points out that QSs are responsible for delivering accurate and thorough cost estimates to customers and contractors. Accordingly, these estimates serve as the foundation upon which project budgets are created for SMCs, who frequently work with limited financial resources.

Procurement is an essential component of project success which Nkado and Meyer (2001) link to the services rendered by QSs to SMCs, particularly in the selection of subcontractors, suppliers and during

tendering of work. Hence, Chan *et al.* (2018) add that a QS is critical in ensuring that procurement decisions are not only cost-effective, but also meet the quality and performance criteria of the project. In a previous study, Aibinu and Jagboro (2002) noted that the QS' vigilant inspection enables the early discovery of cost-saving possibilities and the execution of proactive actions to keep the project costs on track. Thus, QSs promote the notion of value engineering by actively looking for alternate materials, building methods, and design changes that can save money without compromising on project quality and functionality (Choi & Staley, 2021; Smith, 2017). This strategy aligns with the resources constraints that SMCs frequently confront, which demand resource optimisation in the delivery of projects, as alluded to by Welle, Haymaker, Fischer and Bazjanac (2014).

Administratively, QSs are reportedly noted as pivotal in contract administration SMCs' projects which enable these enterprises to manage complex contractual arrangements (Tjano, 2019). Considering the inevitability of variations in the dynamic building environment, Dikgang and Mbachu (2020) argue that QSs are better skilled in determining the impact of these changes on costs and timelines related to SMCs' projects. Furthermore, Dikgang and Mbachu (2020) add that QSs protect SMCs against financial risks by creating a comprehensive financial risk management plan, implement and control the plan during project implementation. QSs achieve the latter by valuing work done by SMCs, adjudicating any contractual claims, as well as reviewing and certifying payment applications from contractors and subcontractors (Aouad *et al.*, 2003). In a way, QSs ensures that payments are given correctly and equitably, in accordance with the task accomplished. Furthermore, upon project completion, QSs support SMCs by preparing and negotiating the final account (Ashworth & Hogg, 2013). Therefore, when reflecting on the highlighted services rendered by QSs to SMCs in other contexts, it is undisputable that their role is critical in catalysing the success of SMCs within the Namibian context.

Research Methodology and Method

The study employed a quantitative approach to gather data from registered professional quantity surveyors and owner-managers of small and medium-sized contracting firms, using a self-administered questionnaire survey tool. Leavy (2017) points out that a quantitative approach enables objective evaluation and generalisability of the results. Hence, the study adopted the approach to examine the level of impact that Namibian Quantity Surveyors pose on SMCs' private sector projects with the aim of generalising the results within the Namibian context. The study was confined to Windhoek since it is the capital city and economic hub of Namibia where most quantity surveyors and SMCs are headquartered. Quantity surveying professionals were drawn from the list of the Institute of Namibian Quantity Surveyors (INQS), while owner-mangers were selected from a list of SMCs which was developed using convenient and snowball sampling, since there is no regulation in Namibia which compels SMCs to be registered at central point. Offei, Kissi and Nani (2019) confirm that snowballing is most appropriate when confronted with difficulties in identifying respondents who are acquainted with the phenomenon. Following the identification of thirty-nine (39) SMCs, and the fact that there are thirty (30) registered quantity surveying consultant firms in Namibia, a census was employed, thereby distributing the questionnaires to all the targeted respondents. Some questionnaires were physically delivered to the respondents, while others were emailed to them. Kaur (2017) demonstrates that a larger sample size improves data validity, hence if the sample frame is small, it is recommended that the study considers the whole population. The adopted questionnaire had two sections, of which the first section considered the respondents' demographic variables such as educational level and work experience. The second section sought to probe the insights of respondents on the contributions of quantity surveyors towards the delivery SMCs' private sector projects in Namibia. Respondents were asked to rate the frequency at which they exhibited the identified key roles of quantity surveyors, in the delivery of SMCs' private sector projects in Namibia, using a five-point Likert scale, with 1- Very low contribution/impact, 2 – Low contribution/impact, 3 – moderate, 4 –High contribution/impact, and 5 – very high contribution/impact. The reliability of the collected data was evaluated using the Cronbach's Alpha coefficient. George and Malley (2016) posit that values exceeding 0.7 are considered highly reliable. The questions tested had Cronbach's Alpha values greater than 0.7, hence implying that there is a high correlation between the respondents' answers, making the collected the data reliable. The data was analysed through the computation of mean scores (MSs) and their ranking. The range of interpreting the 5-point Likert scale mean score was given as follows: $MSs > 1.00 \leq 1.79$ (Very low contribution/impact), $MSs > 1.80 \leq 2.59$ (Low contribution/impact), $MSs > 2.60 \leq 3.39$ (Moderate), $MSs > 3.40 \leq 4.19$ (High contribution/impact) and $MSs > 4.20 \leq 5.00$ (Very high contribution/impact).

Research Results

Response rate

Questionnaires were distributed to owner-managers of SMCs and principals of quantity surveying firms in Windhoek. A total of 69 questionnaires were distributed, with 11 being administered as hard copies, while the remaining 58 were administered online via Google Forms for easy accessibility to the targeted respondents. A response rate of 64% was attained. The response rate aligns with findings from a previous study by Moser and Kalton (1979) who argue that survey results could be biased and of limited value if the return rate fell below 30%-40%. This is corroborated by Sauro and Lewis (2016) who posit that a response rate between 21 and 28 respondents could yield accurate, low-risk data. Consequently, the response rate obtained is deemed adequate for subsequent statistical analysis.

Table 1: Response rate

Data collection tools	Target population	Responses archived	Respondents rate (%)
Questionnaires for Small Medium Contractors	39	23	58
Questionnaires for QS firms	30	21	70
TOTAL	69	44	64

Demographic information of respondents

Table 2 shows the demographic information of the respondents related to the work experience and educational qualifications.

Table 2: Demographic information of respondents

Category	Frequency	Percentage
Work experience		
1-5 years	6	15
6-10 years	15	33
11-15 years	17	38
16-20 years	4	10
25 + years	2	4
Total	44	100
Educational qualification		
National certificate	5	11
Diploma	10	23
Bachelor's Degree	27	62
Master's Degree	2	4
Doctorate	0	0
Total	44	100

From Table 2, most of the respondents had work experience ranging between 6 to 15 years (49%), while only 3% had work experience above 25 years. However, when comparing the work experience of owner-managers and quantity surveyors, the results show quantity had more experience than owner-managers, with 80% of the quantity surveyors having work experience of above 10 years, while 70% of the owner-managers of SMCs possessed work experience of below 10 years.

Pertaining to educational qualifications, most of the respondents were holders of bachelor's degrees (62%), followed by 23% with Diplomas, while 11% possessing national certificates. Among those with bachelor's degrees, 95% were quantity surveyors, with the remaining being for owner-managers. Hence, quantity surveyors were more educated compared to owner-managers of contracting firms.

Quantity surveyors' contributions in SMCs' private sector projects

The study assessed the contributions of quantity surveyors to the delivery of projects executed by SMCs in the private sector in Namibia. Table 3 shows how owner-managers and consultant quantity surveyors viewed the contributions of quantity surveyors towards SMCs, based on the factors identified in literature. The range of interpreting the 5-point Likert scale mean scores was given as follows:

MSs>1.00 ≤ 1.79 (Very low contribution), MSs>1.80 ≤ 2.59 (Low contribution), MSs>2.60 ≤ 3.39 (Moderate), MSs>3.40 ≤ 4.19 (High contribution) and MSs>4.20 ≤ 5.00 (Very high contribution).

The mean scores revealed that quantity surveyors make very high contributions to SMCs operating in private sectors through the preparation of bills of quantities, with a mean score of 4.6, preparation and settling of final accounts, with a mean score of 4.6, cost planning, with a mean score of 4.5, projects planning with a mean score of 4.3. Furthermore, respondents perceived high contributions in tendering and tender adjudication, with a mean score of 4.0, the preparation of interim and final valuation, with a mean score of 3.9, measurement of variation and agreeing claims, with a mean score of 3.7. However, services which were rated between MSs>2.60 ≤ 3.39 are deemed moderately offered by quantity surveyors to the SMCs in the Namibian private sector, such as contract administration, with a mean score of 3.3 and value management or engineering, with a mean score of 3.3. On the other hand, the findings reveal that services like cost auditing and monitoring, with a mean score of 2.2, cost modelling, with a mean score of 2.0, defending contractual claims, with a mean score of 2.0 and expert witness/arbitration, with a mean score of 2.0 are lowly offered, while feasibility studies, with a mean score of 1.3 is very lowly offered by quantity surveyors towards SMCs in Namibia's private sector.

Table 3: Quantity Surveyors' contributions towards SMCs' private sector projects

Quantity Surveyors' contributions in SMCs' private sector projects	N	Mean Score	Ranking
Preparation of Bill of Quantities	44	4.6	1
Preparing and settling of final accounts	44	4.5	2
Cost planning	44	4.5	2
Project planning	44	4.3	4
Tendering and tender adjudication	44	4.0	5
Preparation of interim and final valuation	44	3.9	6
Measurement of variation and agreeing claims	44	3.7	7
Contract administration	44	3.3	8
Value management or engineering	44	3.0	9
Cost auditing and monitoring	44	2.2	10
Cost modeling	44	2.0	11
Defending contractual claims	44	2.0	11
Expert witness/arbitration	44	2.0	11
Feasibility studies	44	1.3	14
Valid N (listwise)	44		

Although the results show that quantity surveyors play a critical role in stimulating the delivery of SMCs' private sector projects, most of the essential services are marginally offered the SMCs within the Namibian private sector.

Impact of quantity surveyors in the delivery of SMCs' private sector projects

The study asked respondents on how they viewed the impact of quantity surveyors' contribution in the delivery of SMCs' private sector projects, based on several parameters related to successful project delivery. Table 4 indicate the results of the study. The range of interpreting the 5-point Likert scale mean scores was given as follows: MSs>1.00 ≤ 1.79 (Very low impact), MSs>1.80 ≤ 2.59 (Low impact), MSs>2.60 ≤ 3.39 (Moderate), MSs>3.40 ≤ 4.19 (High impact) and MSs>4.20 ≤ 5.00 (Very high impact).

Table 4: Impact of quantity surveyors in the delivery of SMCs' private sector projects

Impact Quantity Surveyors on SMCs' private sector projects	N	Mean Score	Ranking
Accurate cost estimation	44	4.3	1
Procurement	44	4.3	1
Completion within budgeted cost	44	4.3	1
Drafting final accounts	44	4.2	4
Timely Completion	44	4.2	4
Cost management	44	4.1	6
Resource allocation	44	4.0	7
Cost savings	44	3.8	8
Good quality buildings	44	3.2	9
Expert advice	44	3.0	10
Legal compliance	44	3.0	10
Dispute resolution	44	3.0	10
Project management and administration	44	2.5	13
Project Feasibility	44	2.3	14
Project viability	44	2.1	15
Valid N (listwise)	44		

From Table 4, the results show that, out of 15 parameters identified for measuring successful completion of SMC projects in the private sector, QSs have very high impact on three aspects which include accurate cost estimation, procurement and completion within budgeted cost, with mean scores of 4.3. Additionally, the mean scores which within $MSs > 3.40 \leq 4.19$ indicate that the contribution of quantity surveyors have been highly impactful in meeting such parameters in the delivery of SMCs' private sector projects. Thus, the findings reveal that QSs have high impact in services which include drafting of final accounts, with a mean score of 4.2, timely completion, with a mean score of 4.2, cost management, with a mean score of 4.1, resource allocation, with a mean score of 4.0 and cost savings for the SMC during execution of work on site, with a mean score of 3.8. However, services like attainment of good quality buildings, with a mean score of 3.2, expert advice, with a mean score of 3.0, legal compliance, with a mean score of 3.0, dispute resolution, with a mean score of 3.0, were found to moderately impacted by QSs since they fall within $MSs > 2.60 \leq 3.39$. Owner-managers rated below 2.60 in aspects which they felt that quantity surveyors lowly impacted such as project management and administration, within a mean score of 2.5, project feasibility, with a mean score of 2.3 and project viability, with a mean score of 2.1. The mentioned three factors were considered lowly influenced by QSs, hence the need to develop mechanisms for improving QSs' contributions in such aspects for the effective delivery of SMCs' private sector projects.

Discussion

The findings of the study largely align with the literature that highlights the crucial role of Quantity Surveyors (QSs) in the delivery SMCs' projects in most developing countries (Dwivedi & Dwivedi, 2021, Dikgang & Mbachu, 2020, Wao & Flood, 2016). The results confirm that QSs provide essential services such as cost estimation, project cost control, and project planning, thus consistent with the extant literature which recognises these roles as fundamental to the successful execution of projects by SMCs (Tjano, 2019). Consequently, the study found that QSs' contributions culminated in accurate cost estimation, effective procurement, completion of projects within budget, timely conclusion of final accounts, timely completion of projects and effective cost management, which positively impacted the delivery of SMCs' private sector projects. These findings are further supported by Dikgang and Mbachu (2020) who submit that QSs are instrumental in protecting SMCs against financial risks.

It is noteworthy to mention that, despite the notable contributions of QSs to the SMCs in the Namibian private sector, the study found that many SMCs working on private sector projects in Namibia are deprived from several essential services which include value management, contract administration and defending contractual claims. As such, the services of QSs have insufficiently addressed the attainment of good quality buildings, expert advice, promotion of legal compliance, dispute resolution, project management and administration, project feasibility, and project viability, of which the mentioned aspects are crucial for the effective delivery of SMCs' private sector projects. However, these findings are disputed by some scholars who found that value management and contract administration are among the critical services that QSs render to SMCs in countries like Zimbabwe (Munaka, Moyo & Dhlwayo,

2023a) and South Africa (Smith, 2017). Likewise, Choi and Staley (2021) assert that QSs promote value engineering by actively looking for alternate materials, building methods, and design changes that can save money without compromising on project quality and functionality. Nonetheless, the current study which shows that the concept of value engineering is lowly offered to SMCs in Namibia as confirmed by a low rating of 3.0, demonstrates contextual differences, of which QSs in Namibia could draw lessons from other contexts to improve their collaborative efforts with SMCs in the private sector for improved project delivery.

Conclusion

SMCs remain the engine for driving infrastructure development in the private sector, although the delivery of their projects is impeded by a myriad of challenges. The role of Quantity Surveyors is widely viewed as cardinal to improve the delivery of SMCs' private sector projects. The current study therefore sought to assess the impact that quantity surveyors pose in the delivery of SMCs' private sector projects within the Namibian context. Based on the results, quantity surveyors indeed play a crucial role in enhancing the successful execution of SMCs' private sector projects in Namibia. QSs' expertise in various domains such as cost estimation, procurement, risk management, and project coordination significantly contribute to improved project outcomes and stakeholder satisfaction. The study found that QSs assist SMCs in the private sector by developing accurate cost estimates, improved procurement of works, goods and services, completion of work within budget, preparation of final account and timely delivery of projects. Thus, the study underscores the importance of quantity surveyors in the construction industry and highlights their indispensable contribution to the success of SMCs' private sector projects.

Despite the significant role played by quantity surveyors, it is noteworthy to mention that their influence on the successful execution of SMCs' private sector projects in Namibia remains low, relative to most contexts. Based on the findings of the current study, QSs in Namibia have had low impact in the attainment of good quality buildings by SMCs, providing expert advice, promoting legal compliance, dispute resolution and project management and administration, which ultimately stimulate the effective delivery of SMCs' private sector projects in the country.

Therefore, the results of the study offer several practical contributions to stakeholders in the private sector. For instance, the findings could assist both QSs and SMCs in the private sector in Namibia to identify areas that require collaboration to improve the delivery of projects for private sector clients. Secondly, QSs could transform their roles to ensure that they are more accessible to SMCs in the private sector. Moreover, the results could be insightful to similar contexts in the Global South. However, while the results of the study are insightful, the small sample size and a mono-method quantitative approach used, preclude the findings from being generalised. Hence, future research could adopt a mixed method approach and a larger sample size to improve data validity. Additionally, further research could explore specific strategies and best practices for integrating quantity surveyors into SMCs' project teams to maximise their positive influence on project outcomes.

Recommendations

Based on the results, it is recommended that SMCs in Namibia prioritise the involvement of quantity surveyors in their project management processes to enhance project success. It is further recommended that quantity surveyors and SMCs enhance collaboration and communication throughout the project lifecycle. Clear communication channels and regular coordination meetings can help ensure that quantity surveyors' expertise is effectively utilised and integrated into project decision-making processes. Additionally, both quantity surveyors and SMCs should invest in continuous professional development to stay updated with the latest industry trends, technologies, and best practices. This will enable quantity surveyors to enhance their skills and knowledge, thereby maximising their contribution to project success. Therefore, it is recommended that small medium contractors use professional quantity surveyors to their full potential of roles for an enhanced project success rate.

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The Impact of the Black Economic Empowerment Policy on Emerging Contractors in South Africa

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Abstract

The South African government has adopted several initiatives such as Black Economic Empowerment (BEE) in public procurement to encourage social equality and eliminate racial prejudice against the black community to improve them socio-economically. The study investigates the impact of the BEE policy on emerging contractors since its introduction. A quantitative approach was used to distribute questionnaires to 56 construction professionals using convenience sampling techniques, of which 37 responded. The data received were analysed using SPSS to derive the mean values. The findings show that BEE policy is riddled with corruption. However, BEE has transformed emerging contractors socio-economically. This demonstrates that despite the implementation issues of the BEE policy, it provides contractors with opportunities. Despite the successes of the BEE policy, corruption challenges negatively impact the public procurement of emerging contractors in South Africa. Thus, for corruption to be eradicated, transparency should be improved in contractor appointments. The paper has identified the successes and challenges of the BEE policy, which may guide policy direction for policy implementers.

Keywords: Barriers, BEE Policy, Emerging Contractor, Implementation.

Introduction

Many South Africans were previously excluded from national socio-economic events and activities. As a democratic nation with a democratic government since 1994, South Africa has attempted to ensure the distribution of resources equally and fairly among the population for economic expansion.

The South African government has adopted several ideas and initiatives over the years that are meant to mend the country. Some of these changes were made to encourage social equality, end racial discrimination against the black population and change the environment of the country socio-economically. However, little has changed since these ideas and policies were put into practice (South Africa Government, 2021). One such initiative is implementing preferential procurement guidelines, known as the black economic empowerment (BEE) policy framework (Kajimo-Shakantu and Root, 2006). The Black Economic Empowerment concept (BEE) is intended to enhance the economy and improve black businesses. According to Act 53 of 2003, BEE was established to promote, among other things, black economic empowerment (BEE Act, 2003). Since BEE was introduced and implemented, it has caused a few questionable actions that have resulted from fraud and corruption, political interference in decision-making and a lack of accountability strategies (Shava, 2021). With such problems rising, the government must carefully and effectively monitor this policy. It could work better and further accelerate the economic opportunities for the black population (Shava, 2021).

In the 1990's, BEE was a policy that only focused on transferring ownership to black people; this proved an issue as only a handful of people in the public eye benefited (Sanchez, 2006). Since BEE was seen as a narrowly based strategy because not all people who were supposed to benefit benefited (Sanchez, 2006). However, the government combated this problem; they reviewed the policy by renaming it 'Broad-Based Black Economic Empowerment'. This particular change of name was a stance that allowed the whole society to be more engaged with the policy (Sanchez, 2006). The late former president Nelson Mandela and the ANC had both anticipated that BEE would result in economic progress, social development, and political democracy for the people of South Africa (Shava, 2021). Corruption caused by BEE has increased at all government levels (Kruger, 2016).

The South African government focused on the construction industry's transformation to enable new and small contractors to participate. However, this was destined to fail because these contractors needed more expertise and competencies to work for sustainable construction businesses (Ntuli and Allopi, 2013). Additionally, the emerging contractor policies implemented were meant to use BEE to create job opportunities, which added to the overcrowding of the emerging market (Thwala and Mvubu, 2008). The National Contractor Development Programme (NCDP) was developed by the Construction Industry Development Board (CIDB) and the Department of Public Works to reduce the lack of experience and problems, capacity and business knowledge by assisting and empowering formerly disadvantaged people and potentially emerging contractors in South Africa (Ntuli and Allopi, 2013).

Ogunde et al. (2016) reported that customers are unsatisfied with their projects because certain expectations still need to be met. This is linked to small building contractors who cannot compete with big construction companies due to a lack of funding (Mafimidiwo and Iyagba, 2015). The other major problem that the BEE concept brought about since its implementation is the lack of finance by BEE firms because lending money to BEE firms is very risky as the capital available has very high interest rates, causing the firms to service the debt instead of being empowered by the transaction (Shange, 2012). BEE was introduced and implemented as an economic empowerment policy to help uplift the black population socio-economically by awarding tenders for government projects. However, the impact of the BEE policy on the emerging contractors who are key policy beneficiaries has yet to be made known in the literature. For instance, Horwitz & Jain (2011) assessed the Equality, Diversity and Inclusion of the BEE policy; Akenroye et al. (2020) SME capacity to partake in procurement; Ferreira and de Villiers (2011) checked firm's BEE score and their performance on the market. More recently, Amoah (2024) examined the BEE challenges. This research evaluated BEE's impact on emerging contractors in South Africa since its introduction in the public procurement process.

Literature Review

The BEE policy and objectives

According to Mparadzi & Kalula (2007), BEE is the solution to improve and rectify the economic imbalances commemorating the apartheid era. Osode (2004) noted that the BEE policy is proposed to transform the economy of South Africa by consolidating the previously disadvantaged South Africans to have greater participation in the economy to achieve economic justice. A council for BEE was brought forward to identify the black majority's problems regarding participation, which gave birth to the BEE strategy (Horwitz and Jain, 2009). According to the "bottom-up" tactic, black economic empowerment aimed to speed up and provide assistance in the apparent non-racial representative government in South Africa. Shwala (2018) stated that the most common and usually more acceptable theme is that if black people, collectively and individually, could become wealthy and successful, political change would be enabled to take place more quickly and efficiently. Shwala (2018) explained that BEE was regarded as a mechanism in the late 1980s and early 1990s to create a middle class of black people interested in the economy. It was thought that this policy would ensure political stability and a market economy if the racial composition of the ownership structure were partly rearranged.

With this information, one can deduce that apartheid was not beneficial for business and did not make economic sense regarding the new expectations the international economy brought. Shwala (2018) further argued that BEE could be viewed as having a 'trickle-up' effect where the government is transformed from the bottom up. This concept and policy were created after 1994 to appease the new administration. Businesses were sold to black empowerment organisations, and black non-executive directors were appointed when the African National Congress (ANC) assumed control (Shwala, 2018). Since 1994, the ANC government has been finding it challenging to define the BEE as a definite policy that can be used to help the previously disadvantaged majority and not just the black elite.

According to the BEE Act (*Act 46 of 2013*), the viable economic empowerment of all black people, particularly women, workers, youth, people with disabilities, and people living in rural areas, is achieved through diverse but integrated socio-economic strategies. The objectives of the BEE *Act 46 of 2013* are to facilitate broad-based black economic empowerment through the strategies indicated in Figure 1.

Objectives of the BEE policy

- promoting economic transformation by increasing black people's economic participation.
- Changing the composition of black ownership and management structures in the existing and new enterprises.
- increasing communities, workers, cooperatives and other collective enterprises' ownership and management of existing and new enterprises
- increasing blacks' access to economic activities, infrastructure, and skills training
- increasing the black women's ownership and management of existing and new enterprises
- promoting investment ventures that allow meaningful participation of blacks in the economy to achieve sustainable development and general prosperity.
- empowering rural and local communities access to economic activities, land, infrastructure, ownership, and skills
- promoting access to finance for black start-ups, small, medium, and micro enterprises, co-operatives, and black entrepreneurs.
- increasing the effective economic participation of black-owned and managed enterprises and enhancing their access to financial and non-financial support

Figure 1: Objectives of BEE policy
Source: Author construct (2023)

The application of BEE in the public procurement

In its 1997 Green Paper on Public Sector Procurement Reform, the government made clear that it intended to use public procurement to accomplish several socio-economic objectives. As a result, Broad-Based Black Economic Empowerment (BBBEE), also known as Black Economic Empowerment, was developed and put into practice (van der Merwe and Ferreira, 2022). The government incorporated a few measures to ensure people comply with the BEE policy. The government decided to spend money on the preferential treatment of procurement towards entities that comply with BEE and grant licences to organisations that comply with BEE (Ponte and Van Sittert, 2007). Ferreira & de Villiers (2011) noted that this preferred treatment is defined as "contracting with persons, or categories of persons, historically disadvantaged by unfair discrimination based on race, gender, or disability" under the Preferential Procurement Policy Framework Act of 2000 (South Africa, 2000). The government published a revised act that explicitly incorporates the use of BEE levels in establishing preferential procurement (van der Merwe and Ferreira, 2022).

The government realised that if BEE only influences industries requiring government licenses or industries that deal with the government directly, then BEE would not impact a broader range of industries in South Africa. This led to the development of the Codes of Good Practice. The codes brought an action for BEE called the "BEE-rating" that required an enterprise to acquire a BEE score or rating. The codes were developed by an economic development rating agency (van der Merwe and Ferreira, 2022). The government then uses these scores to show a preference for higher-rated enterprises. Preferential procurement is one of the elements of the BEE score. A higher BEE score will be awarded to the acquiring entity if most owners are previously disadvantaged people. The BEE requirement became more appealing for businesses that do not directly provide to the government (van der Merwe and Ferreira, 2022).

The challenges of BEE policy implementation in the procurement process

The connection between emerging contractors and public procurement is slowly becoming prevalent in policy and academic settings. This results from the probable contributions that emerging contractors can make to a country's economy by improving living standards, creating jobs and providing services and goods (Akenroye et al., 2020). In most industries, such as construction, emerging contractors are regarded as innovation drivers. The government seeks to benefit by associating with them to resolve the more intricate challenges involved in public services. Public organisations can increase supplier

diversity by engaging with emerging contractors and increasing variation through procurement (Akenroye et al., 2020). Emerging contractors have many skills and attributes that set them apart from established contractors. These attributes include being agile, flexible, and able to offer services specifically made for that particular project. This can be used as an advantage when they bid for contracts in the public sector. Despite their contribution to the country's economic development, the participation rate and success of winning public contracts are higher for emerging contractors than their larger counterparts (Akenroye et al., 2020).

According to researchers Akenroye et al. (2020), emerging contractors must compete more on the same level as large-scale contractors in terms of resources and size. Hadebe (2017) noted that business opportunities and employment for previously disadvantaged communities and people are given through targeted procurement and numerous techniques, which all aim to produce opportunities for a specific enterprise. Thus, the BEE policy aimed to transform the economy and include more black people, explicitly emerging contractors. Another contributing factor to the BEE policy was the deliberate placement of black South Africans in a lower place to prevent them from contributing to the community freely, resulting in many inequalities and inconsistencies. The BEE policy was introduced to strengthen South Africa's economy to meet the needs of the people; however, because this policy was not implemented correctly, the people who were meant to benefit from the policy became frustrated and soon pointed out that this policy lacks commitment and that it may not meet the objectives it was intended to achieve (Hadebe, 2017). Therefore, inclusion and transformation in the construction industry became a significant problem.

The most frustrating people were the emerging contractors who needed the necessary skills, resources, expertise and capacity to fulfil the contracts. Therefore, the construction industry was blamed for the poor implementation of the BEE policy; therefore, a new contractor development programme was introduced to encourage growth and create new procurement strategies for those marginalised individuals (CIDB, 2009; CIDB, 2011). The preferential procurement policy was introduced to help the government select businesses owned by the less fortunate, therefore impacting the redistribution of skills and wealth. The BEE Programme was approved to "establish a legislative framework to empower the Minister to issue codes of good practice, publish transformation charters, and establish the BEE Advisory Council (BBBEE, 2003). The programme successfully achieved its objective by awarding and transforming previously disadvantaged individuals with the opportunity to participate in public procurement. However, this programme is not left without criticism as it is seen as a corruption tool.

Emerging contractors in South Africa

In emerging economies such as South Africa, the construction industry is crucial in encouraging economic growth and sustainable infrastructure (Hove, 2016). For a country like South Africa, emerging contractors are important construction drivers of schools, roads, residential, bridges, dams, and power infrastructure. This creates jobs and significantly impacts the country's economic growth, which will furnish social welfare (Hove, 2016). Because, in some instances, contractors may need more equipment and resources to complete a task, such as graders, tractors and tipping trucks, old equipment is usually used, resulting in time delays due to breakdowns and required routine maintenance. Ofori (2000) noted that despite such constraints, emerging contractors usually can complete small-scale projects and should compete at that level, especially in their local scale of influence. In South Africa, contractors enter the lower end of the general building contracts category. The sector seems unsustainable and highly competitive, as confirmed by the Department of Public Works and the CIDB. According to Thwala and Phaladi (2009), policies intended for emerging contractors set for BEE are being used as job creation opportunities, thus overcrowding emerging contractors' markets. BEE changed and transformed the contract giving to white-owned, well-established companies. This aligned with the government's strategy to defeat the economic inequalities of the past. BEE allowed contractors to obtain the necessary skills, knowledge, and technology (Maphanga, 2003).

According to Amoah and Bikitsha (2021), emerging contractors form part of the small, medium, and micro-sized enterprises (SMMEs) that are now defined as businesses in construction that are small in scale, are financially constrained in terms of funding and do not have a solid business structure. These SMMEs, also known as emerging contractors, are critical role players that will help develop the country's economic growth. Emerging contractors generally contribute to the factors essential in promoting and achieving economic growth, namely, social development, the creation of jobs and the economy's

advancement (Amoah and Bikitsha, 2021). The South African construction industry is constantly changing and is being transformed. Due to poor construction knowledge and lack of experience, emerging contractors fail to develop sustainable businesses. This can be resolved by exposing emerging contractors to people with the requirements, knowledge, and experience (Martin and Root, 2012).

Research Methodology

The approach adopted for this study

The researcher used a quantitative research approach by sending questionnaires to collect data. This method aims to determine how the BEE concept impacted the economic growth and emerging contractors and whether it contributed to what it intended. According to Creswell and Creswell (2017), the quantitative research approach allows researchers to test variable and their effects on the population. Therefore, it was appropriate to use a quantitative approach to identify the effect of the BEE policy on emerging contractors.

Target population and sampling

Burns and Grove (1993) defined a population as all elements, namely, objects, events and individuals that fulfil the sample requirements to be included in the study. The population of this study consisted of emerging contractors and construction consultants (PM, QS) in the South African construction industry. Convenience sampling was used to select South African construction industry respondents. The respondents covered the issues and solutions arising from the BEE policy. According to Mouton (1996), a sample can be defined as elements selected to determine the total population from which they are taken. The respondents that could participate in the study had to meet the following criteria to be included in the sample: 18 years or older. They should be willing to participate and mentally sound enough to sign the participant consent form and work in the construction industry. South African citizens can be of either sex or of any race and should be available and willing to be part of the study.

Data collection instrument

A questionnaire was the chosen data collection instrument. Questionnaires have many advantages, including preventing any deviation from the subject of the matter and minimal time to distribute (Burns and Grove (1993)). One questionnaire was used in data collection, consisting of primarily close-ended questions to avoid wasting the respondent's time and provide accessible information for analysis. English was the primary language in the questionnaire as it is the universal language and avoids language barriers. The researcher translated each question if the respondent needed help understanding the questions. The questionnaires were distributed to 56 respondents via email, of which 37 responded after several reminders. The respondents were assured confidentiality. The questionnaire consisted of three sections: A, B, and C. Section A aimed to gain demographic information such as the occupation, number of years working in the construction industry and the sector under which the respondent falls. Section B aimed to determine participants' views on the BEE policy. Section C had a Likert scale question where respondents had to tick from the provided factors. Data was collected after the researchers had received ethics clearance from the UFS ethics committee.

Data analysis

After the data was collected, it was then organised and carefully analysed. The data in this study were analysed using the Statistical Package for Social Sciences (SPSS) method. Descriptive statistics were used to derive the frequency tables and mean values and ranked based on the mean values for all the factors (Thwala and Phaladi, 2009). The demographics of the respondents are indicated in Table 1.

Table 1: Occupation of respondents

Demographics		Frequency	Percentage
Occupation	Construction manager	2	5.41%
	Architect	21	56.76%
	Contractors	9	24.02%
	Quantity surveyors	4	10.81%
	Engineers	1	3.00%
	Total	37	100.00%
Experience in the construction industry	0 to 5 years	8	21.62%
	6 to 10 years	7	18.92%
	11 to 15 years	13	35.14%
	16 to 20 years	5	13.51%
	Over 20 years	4	10.81%
	Total	37	100.00%
Sector of organisation	Private	28	76.00%
	Public	9	24.00%
	Total	37	100.00%
Familiar with the BEE concept	Yes	37	100.00%
	No	0	0.00%
	Not sure	0	0.00%
	Total	37	100.00%

Most respondents are Architects (56,76%), whilst 24% are contractors. The analysis shows that 79% of the respondents have worked in the construction industry for over 5 years. 24% of the respondents work in the public sector, and 76% in the private sector. Again, 100% of the respondents indicated familiarity with the BEE concept.

Findings

The participants' views on the BEE policy

Respondents were asked how they would rate certain statements regarding the BEE policy. Table 2 shows the views of the respondents ranked in order of importance. Most respondents believe BEE is riddled with corruption (Mean=4.49) and has assisted previously disadvantaged black citizens (Mean=3.89). Again, the third factor is that the BEE has socio-economically transformed emerging contractors (Mean=3.86), followed by the reduction of foreign firms' involvement in the procurement process (Mean=3.73).

Table 2: Participants' views on the BEE policy

Factors	Total	Mean	SD	Ranking
BEE implementation is riddled with corruption	37	4.49	4.01	1
BEE has helped the disadvantaged black majority	37	3.89	3.51	2
BEE has transformed contractors' socio-economically	37	3.86	3.41	3
BEE has decreased the opportunity for foreign companies	37	3.73	3.38	4
BEE has improved fairness in the procurement system	37	3.70	3.33	5
BEE decreases racial discrimination in the public procurement process	37	3.68	3.35	6
BEE equips contractors with knowledge and skills	37	3.49	3.20	7
BEE policy is not sustainable	37	3.41	3.06	8
BEE policy is poorly implemented	37	3.35	3.01	9
BEE discriminate among citizens	37	2.95	2.74	10
BEE has failed to achieve its objectives	37	2.70	2.43	11

BEE is also believed to have brought fairness in the procurement process (mean=3.70) and decreased racial discrimination in the public procurement process (mean=3.68); enhanced emerging contractors' knowledge and skill (Mean=3.49); BEE policy is not sustainable (Mean=3.41); BEE policy is poorly implemented (Mean=3.35); BEE discriminates among citizens (Mean=2.95); BEE has failed to achieve its objectives (Mean=2.70). These findings indicate that despite respondents' excellent perception of the BEE policy, they also believe it has failed in some respects.

Participants' views on the effect of the BEE policy on contractors

The respondents were also asked to rate their views on the effect of the BEE policy on emerging contractors. The findings are presented in Table 3. The results show that many respondents believe the BEE policy BEE has aided black contractors' access to public contracts (Mean=4.19). This is followed by the belief that BEE has given me more opportunities to emerging contractors (Mean=4.03), improved my capacity of contractors, and has transformed contractors' socio-economically (Mean=3.86); BEE has brought hope to black contractors (Mean=3.76); BEE equips contractors with knowledge and skills (Mean=3.65).

Table 3: Participants' views on the effect of the BEE policy on contractors

Factors	Total	Mean	SD	Ranking
BEE has aided black contractors' access to public contract	37	4.19	3.73	1
BEE has given me more opportunities	37	4.03	3.53	2
I do not have a connection with the government to get the contract because of the BEE policy	37	3.92	3.59	3
BEE has improved my capacity as a contractor	37	3.86	3.44	4
BEE has transformed contractors' socio-economically	37	3.86	3.41	4
BEE has brought hope to black contractors	37	3.76	3.32	5
BEE equips contractors with knowledge and skills	37	3.65	3.28	6
I have won contracts because of my BEE status	37	3.03	2.77	7
BEE policy has helped me get mentorship for my business	37	2.92	2.54	8
BEE policy has helped me get access to the equipment needed for my business	37	2.27	1.97	9
BEE policy has helped me get financial support for my business	37	2.16	1.85	10

Others believe that the BEE policy helped them to win contracts (Mean=3.03). However, significant people think you need a connection with government officials to win contracts despite the BEE policy (Mean=3.92); the least-rated factors are that BEE policy has helped people to get mentorship training (2.92), BEE policy has helped me get access to the equipment needed for my business (Mean=2.27), and BEE policy has helped me get financial support for my business (2.16). These findings show that the BEE has positively impacted emerging contractors; however, some challenges must be overcome to ensure effective implementation to achieve the desired outcome.

Discussions

Emerging contractors' perceptions of BEE policy

Table 2 indicates the respondents' views on the BEE concept in the South African construction industry. Respondents have stated that implementing the BEE concept is riddled with corruption. This shows that as much as the policy brought about change amongst the previously disadvantaged black majority, it still did not fall short of any mischievous behaviour from procurement officials. Past studies have also recognised the corruption aspect of policy implementation. For instance, Pike et al. (2018) found that BEE implementation encourages corruption with tenders where tenders are awarded to businesses that do not meet the requirements of the BEE criteria, resulting in economic strain. The above results support the statement that many respondents had a problem with corruption in the policy. Surprisingly, although the policy excludes some sections of the citizen, respondents do not consider discrimination worrisome and rated this among the factors. However, generally, respondents have good perceptions of the BBE policy, which is encouraging news for the government as people are embracing the policy objectives. According to Mparadzi & Kalula (2007), BEE is the solution to improve and rectify the economic imbalances commemorated during the apartheid era. Osode (2004) further noted that the BEE policy is proposed to transform the economy of South Africa by bringing together the previously disadvantaged South Africans to have greater participation in the economy to achieve economic justice. This was proven true from the results presented above as the respondents believe that BEE has helped the disadvantaged black majority and transformed contractors' socio-economically.

Impact of the BEE policy on the growth of emerging contractors

This study sought to investigate how the BEE policy influences the growth of emerging contractors in South Africa. Most respondents claimed that BEE increased access to public contracts and socio-economically transformed them. The policy has also given contractors more opportunities to emerging contractors and improved their capacities. One of the cardinal policy objectives is to promote economic transformation by increasing black people's economic participation. The findings of the study indicate that this policy objective is fulfilled. According to Akenroye et al. (2020), the participation rate and success of winning public contracts for emerging contractors have remained the same as their larger counterparts despite their contribution to developing the economy. However, the results from the study prove otherwise, as most respondents indicated that the BEE policy provided access to public contracts. This is because emerging contractors have many skills and attributes that set them apart from established contractors. These attributes include being agile, flexible, and able to offer services specifically made for that project and thus, the government and big contractors engage them in many projects. However, the policy has not realised the objective of increasing black start-ups, small, medium, and micro enterprises, co-operatives, and black entrepreneurs' access to finance and non-financial. The emerging contractors' least rated factor is that BEE did not help them get financial and equipment support for their business. This may indicate that due to the government's limited financial resources, the intention of assisting emerging contractors financially to sustain them has not materialised. This result correlates with Maphanga (2003), which suggests that the government's strategy faces challenges in defeating the past's economic inequalities and allowing contractors to obtain the necessary skills, knowledge, and technology. Additionally, Amoah and Bikitisha (2021) stated that emerging contractors form part of the small, medium, and micro-sized enterprises (SMMEs) that are now defined as businesses in construction that are small in scale, are financially constrained and do not have solid business structure. These SMMEs, also known as emerging contractors, are the critical role players that will help develop the country's economic growth.

The implication of the findings

The finding implies that despite the success of the BEE since its introduction, the policy has yet to achieve some of the critical objectives. These are mainly due to corrupt practices perpetuated by policy implementers, especially at the tender stage, preventing some beneficiaries from benefiting from the policy. Again, the government's limited resources might have contributed to her ability to provide the necessary financial and non-financial support, as anticipated, thus limiting the capacities of the emerging contractors to execute some substantial public projects. The government must, therefore, re-examine the policy and ensure its sustainability.

Conclusion

The study aimed to assess how the BEE concept in South African procurement has impacted emerging contractors. The study revealed that implementing the BEE policy created significant challenges for emerging contractors in South Africa, including financial barriers and corruption. However, BEE helped contractors acquire state contracts and changed their socio-economic status. Emerging contractors require the BEE concept to develop because they are significant GDP contributors.

Recommendations

Therefore, the study recommends that the government improve the mentorship and training of emerging contractors. Emerging contractors must seek self-development and training by attending workshops that will equip them with the necessary knowledge and skills and expose them to other experienced contractors. Procurement processes should be transparent, and those who take advantage to amass wealth are punished accordingly. Due to the small sample size, the study's findings cannot be applied to the entire population of South Africa. However, it is still important because they shed light on the BEE principle and its difficulties in the construction industry.

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