BUILDING SMART, RESILIENT AND SUSTAINABLE INFRASTRUCTURE IN DEVELOPING COUNTRIES

Edited by
Innocent Musonda and Erastus Mwanaumo

BUILDING SMART, RESILIENT AND SUSTAINABLE INFRASTRUCTURE IN DEVELOPING COUNTRIES

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries contains the papers presented at the International Conference on Development and Investment in Infrastructure (DII-2022). The contributions cover a wide range of topics related to infrastructure issues on the African continent:

- Sustainable Infrastructure Development
- Smart Infrastructure and Cities
- Quality and Resilient Infrastructure
- Education, Empowerment, Gender Equity, Wellness and Development
- Environmental and Waste Management/Facilities & Real-Estate Management
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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries evaluates innovations, empowerment, growth and sustainable development of infrastructure development in Africa, and aims at administrators, academics, and professionals.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries

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Preface

On behalf of the Organising Committee, I welcome you to the International Conference on Development and Investment in Infrastructure (DII-2022). The DII-2022 conference is part of the DII Conference series on Infrastructure Development and Investment in Africa. It aims to provide an international forum for leaders, researchers, practitioners and other stakeholders in infrastructure development to discuss and devise ways of maximising benefits from infrastructure development in Africa and achieve outputs that will inform policy.

The 2022 conference, themed “Building Smart, Resilient and Sustainable Infrastructure in Developing Countries will address a broad range of topics around infrastructure to evaluate and draw lessons on innovations, empowerment, growth and sustainable development.

The broad topics covered by the conference include:

- Sustainable Infrastructure Development
- Smart Infrastructure and Cities
- Quality and Resilient Infrastructure
- Education, Empowerment, Gender Equity, Wellness and Development
- Environmental and Waste Management/Facilities & Real-Estate Management
- Infrastructure, Investment and Finance- Trends and Forecasts
- Infrastructure: Shock Events, Procurement, Project Management, Health & Safety
- Infrastructure: Economic, Social/Environmental Sustainability
- Digital Innovation and transition in the built environment

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

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

Innocent Musonda
For/DII-2022

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Declaration and the peer-review process

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

The peer-review process

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

The first stage of the review

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

The second stage of the review

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

Third stage review

Authors whose papers were accepted after the second review was provided with additional anonymous reviewers' comments on evaluation forms and requested to submit their revised full papers. Evidence was required relative to specific actions taken by the authors regarding the referees' suggestions. After satisfactory evidence was provided, final papers were only accepted and included in the proceedings. To be eligible for inclusion, these papers were required to receive a unanimous endorsement by all the reviewers that the paper had met all the conditions for publication. Of 85 submissions, 34 papers were finally accepted and included in the DII-2022 conference proceedings.

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

Regards
Innocent Musonda
Chair: Scientific Programme

Peer review process (PRP) confirmation

On behalf of the DII-2022 International Conference on Infrastructure Development and Investment Strategies for Africa, we confirm that the manuscripts accepted for oral presentation and publication in the Conference proceedings were blind peer-reviewed by two (2) or more technical specialists.

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

Regards,
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Acknowledgement

The Organising Committee of the DII-2022 is grateful to the Development Bank of South Africa (DBSA) for sponsoring the conference. Their invaluable contribution supports making the proceeding of the conference open access and available to readers.

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

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

We are grateful to all the Keynote speakers, authors, poster presenters, the Organizing and Scientific Committees, reviewers, and the session chairs for contributing to the success of DII-2022. Their invaluable contribution helped us achieve insightful discussions at the conference.

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Sustainable infrastructure development

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Biogas production potential from co-digestion of composted faecal sludge mixed with rice husks and sawdust

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ABSTRACT: The global demand for energy is increasing, with 80% of total energy obtained from fossil fuels rich in greenhouse gases. Biogas is an effective alternative to fossil fuels. Thus, this study aimed at evaluating biogas production potential from co-digestion of composted faecal sludge (FS) mixed with rice husks (RH) and sawdust (SD). FS of 2000g, 3000g was mixed with RH and SD (2mm, 4mm). The ratios for RH and SD were 1:0, 0:1, 1:1, 3:1, 1:3; each mixed with FS, composted for 20days followed by biogas production. Quantity and quality of biogas were measured using water and NaOH displacements, respectively. CH_4 content ranged between 74-76%. Digester with 2000g FS and 100g RH (4mm) performed excellently, producing 17.2L of biogas. Conclusively, RH, SD and FS have potential to produce biogas. However, a comparative study should be done on fresh and composted materials to assess the influence of composting on biogas production.

Keywords: Biogas, Composting, Faecal-Sludge, Rice-husks, Sawdust

1 INTRODUCTION

Globally, 80% of the energy consumed comes from fossil fuels (Ritchie *et al*, 2020). Specifically, in developing countries, 91% of the population entirely depends on the use of biomass consisting of firewood, charcoal, straw and some crop residues as a source of fuel energy for different purposes (Sawyerr *et al.*, 2019). Fossil fuels pose several negative impacts on the environment including air pollution, environmental degradation and health problems such as skin disease and lung cancer (Sawyerr *et al.*, 2019). Also, faecal sludge has been causing serious effects on human health such as the breakout of deadly diseases including cholera and

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typhoid, which is the result of poor sludge management systems like the use of pit latrines. The world's sludge production rate is estimated to be around 45 million dry tons per year *(Karlikanovaite-balikci et al.*, 2019).

Sewage sludge production is expected to increase due to the highly increasing number of populations (Abdel-shafy & Mansour, 2018). Faecal sludge tends to be disposed of improperly, sometimes into the water systems such as rivers which then contribute to the spread of diseases like cholera, diarrhoea and typhoid (Lindberg & Rost, 2018). Thus, the conversion of sewage sludge into useful products is important whereby it can be utilized as a feedstock for biogas production which is a renewable and environmentally friendly source of energy, therefore, solving the problem of energy crisis and fossil fuels while conserving the environment (Agani *et al.*, 2017).

Furthermore, sawdust and rice husks are other common and mostly produced wastes in the environment (Akowuah *et al.*, 2017). Sawdust results from woodworking operations such as sawing, milling, routing, drilling, and sanding. It is composed of small particles of wood that are hazardous to human health, and when inhaled leads to respiratory problems (Akowuah *et al.*, 2017). Rice is the world's third-biggest yield behind maize and wheat and the waste item additionally positions as the world's third-biggest rural residue (Korotkova *et al.*, 2016). Both sawdust and rice husks are the most abundant agricultural residues and they do not tend to easily undergo decomposition by micro-organisms because of their high lignin content composition; due to that, they accumulate in the environment forming a pile producing anoxic condition (Korotkova *et al.*, 2016). These piles have the potential to harbour disease-causing microorganisms such as bacteria and fungus. The materials are usually burnt and sometimes dumped into the environment which then results in the production of greenhouse gases including carbon dioxide and methane that pollute the atmosphere (Azura *et al.*, 2018). However, the two materials contain high content of cellulose which makes them suitable and potential for anaerobic digestion hence becoming the most important source of renewable energy that is a substitute to fossil energy reducing the emission of greenhouse gases such as carbon dioxide into the atmosphere (Wang *et al.*, 2016).

Several studies have been conducted on biogas production by using different substrates such as fruits wastes, poultry and piggery wastes, and cassava peels with cow dung as inoculum (Olukanni et al., 2022; Olukanni and Ojukwu, 2022; Fagbenle and Olukanni, 2021). However, the potential of resource recovery by using rice husk and sawdust with faecal sludge is still being explored. For instance, Karne *et al.*, (2018) did a study on biogas production from faecal sludge at a different temperature ranging for mesophilic (25ºC-45ºC) and thermophilic (50ºC-60ºC). The biogas production rate ranged between 0.06 to 0.12 m^3 per kg of dry mass per day at mesophilic conditions while at the thermophilic conditions the production rate ranged between 0.1–0.21 m^3 per kg of dry mass per day. On the other hand, Syafrudin *et al.*, (2020) conducted research on biogas production enhancement from rice husks pre-treated by NaOH and enzyme, and found out that the pre-treated rice husks using 6% NaOH produced 497ml of biogas while the production using 11% enzyme was 667.5ml with the pre-treated rice husks using 11% enzyme. Matin & Hadiyanto, (2018), also conducted a study on biogas production using rice husk pre-treated with 3% NaOH and reported the highest biogas yield as 63.93ml/g TS. Similarly, Zumalla *et al.*, (2018) performed a study on production of biogas from sawdust pre-treated with 4% NaOH and found the highest production of 709 ml/g per day. However, the study on co-digestion of two lignocellulosic materials, rice husks and sawdust pre-treated with natural method (i.e., composting) with addition of faecal sludge has been rarely investigated.

Therefore, this study aimed at converting these readily available and highly produced environmental wastes (faecal sludge, rice husks and sawdust) into a most useful form of energy (biogas) that is renewable and environmentally friendly through composting (pretreatment) and anaerobic digestion. Hence solving environmental pollutions caused by improper waste management while recovering resources for energy production.

2 MATERIALS AND METHODS

This study was carried out at Ardhi University in Dar es Salaam – Tanzania. The methods used in this study involved experimental setups and laboratory analysis. The major raw materials used in this study were rice husks, sawdust and faecal sludge. The rice (Oryza Sativa) husks were obtained from the local grinding machine in Dar es Salaam and sawdust was purchased from Mwenge carpentry Centre in Dar es Salaam. The faecal sludge was obtained from septic tanks used at Ardhi University

2.1 *Experimental setup*

2.1.1 *Composting*

The in-vessel composting method was used during composting as described by *Manyapu et al.*, (2017). The composter was made of a plastic bottle with a capacity of 12 litres. The experiment was divided into four runs (groups A2, A4, B2 and B4) based on variation in the quantity of faecal sludge (FS) and particle size of the materials (rice husks (RS) and sawdust (SD). Each run contained five sets of experiments based on the mixing ratios. In each experimental run the amount of faecal sludge was kept constant (2000g or 3000g) but the variation was based on the amount of rice husks and sawdust (250g, 500g, 750g, and 1000g) and their particle sizes (2mm and 4mm). Faecal sludge was mixed with rice husks and sawdust at 5 different ratios (1:0, 0:1, 1:1,1:3, and 3:1) for each particle's size making a total of 20 compost bins. The weight of materials was measured by using a weight balance of 100kg capacity. The materials in each compost bin were well mixed to attain homogeneity and allow aeration of the compost. The temperature was monitored daily while pH and moisture content monitoring were done after every four days for 20 days.

2.1.2 *Biogas production*

The biogas production was carried out in a batch reactor system, consisting of 20 reactors systems. The batch reactor system was made of a 6-litre plastic bottle digester containing feedstock materials (composted rice husk, sawdust and faecal sludge). A 1.2 litre invented plastic bottle full of water (gas collection unit). About 0.5 meters in length and 7mm inner diameter hose pipe for conveying gas from the digester to the gas collector. A 1-litre plastic bottle (water collector). The composted materials were used for biogas production with the same mixing ratios used during composting. Before feeding the substrate 1250 ml of water was added to the specified weight of the compost, followed by 500ml (faecal sludge) seed material as shown in Table 1; and then mixed thoroughly to obtain homogeneity. The mixture was fed into the digester. The quantity and quality of the gas were measured daily using the water and sodium hydroxide displacement method, respectively. Ambient temperature was measured on daily basis. The measurement of substrate parameters was performed before feeding the material in the digesters and after anaerobic digestion process. The measured parameters were pH, chemical oxygen demand (COD) and total solids (TS) using the standard methods of analysis (2017).

2.2 *Data analysis and presentation*

All the results were analyzed and figured out using descriptive statistical analysis available in Microsoft Excel 2013 spreadsheet. The statistical comparison was performed using single-factor ANOVA and significant difference offset at $p<0.05$.

3 RESULTS AND DISCUSSIONS

3.1 *Composting*

Raw materials were characterized prior composting and the results are as indicated in Table 2. pH of raw materials ranged from 6.1 to 7.1 in rice husks while faecal sludge had pH of 7.5.

Table 1. The amount of the materials added to the digester, amount of seed material used and volume of water added to the mixture to form slurry.

Exp run	Particle size	Rice husks (g)	Sawdust (g)	Optimized ratios, w/w	Reactor Name	Compost fed in the reactor (g)	Seed material (FS)(g)	Volume of H_20 added (ml)
2000g Faecal sludge								
A2	2mm particle size	1000	0	R_1(1:0)	A_2R_1	2000	500	1250
		0	1000	R_2(0:1)	A_2R_2	2000	500	1250
		500	500	R_3(1:1)	A_2R_3	2000	500	1250
		750	250	R_4(3:1)	A_2R_4	2000	500	1250
		250	750	R_5(1:3)	A_2R_5	2000	500	1250
A4	4mm particle size	1000	0	R_1(1:0)	A_4R_1	2000	500	1250
		0	1000	R_2(0:1)	A_4R_2	2000	500	1250
		500	500	R_3(1:1)	A_4R_3	2000	500	1250
		750	250	R_4(3:1)	A_4R_4	2000	500	1250
		250	750	R_5(1:3)	A_4R_5	2000	500	1250
3000g Faecal sludge								
B2	2mm particle size	1000	0	R_1(1:0)	B_2R_1	2000	500	1250
		0	1000	R_2(0:1)	B_2R_2	2000	500	1250
		500	500	R_3(1:1)	B_2R_3	2000	500	1250
		750	250	R_4(3:1)	B_2R_4	2000	500	1250
		250	750	R_5(1:3)	B_2R_5	2000	500	1250
B4	4mm particle size	1000	0	R_1(1:0)	B_4R_1	2000	500	1250
		0	1000	R_2(0:1)	B_4R_2	2000	500	1250
		500	500	R_3(1:1)	B_4R_3	2000	500	1250
		750	250	R_4(3:1)	B_4R_4	2000	500	1250
		250	750	R_5(1:3)	B_4R_5	2000	500	1250

Organic matter ranged from 41.5 to 54, 22.4% in sawdust and 61.5% in faecal sludge, showing potential of these materials in biogas production. A study done by Afifah & Priadi, (2017) indicated similar results.

Table 2. Physical characteristics of raw materials used in the experiment.

Type of waste	pH	Moisture content (%)	Total solids (%)	Volatile solids (%)	Organic matter (%)
Faecal sludge	7.5	79	21	36.2	64.5
Rice husks (4mm)	7.1	10.7	89.3	53.4	41.5
Rice husks (2mm)	6.1	26	74	73.7	54
Sawdust	7.3	31	69	51	22.4

3.1.1 *Temperature profile and its effect on composting*

It was observed that on the first day of composting the temperature of the mixture was reading the same as the room temperature. On the fourth day, the temperature started rising and the maximum temperature was observed to be 54.5°C and 53.5°C in reactors A_2R_4 and A_2R_2, respectively. On day 6, the higher readings were observed in reactor B_2R_1 and B_2R_4 which was 57.3°C and 49.4°C, respectively. The lowest readings were observed in reactors A_4R_4 (30°C) and B_4R_2 (32°C) while the temperature was moderate for the other reactors. The temperature rise indicates the active phase of composting that involves growth of microorganisms and decomposition of organic matter (Lalremruati & Devi, 2021). From day 8, the temperature for all reactors started to gradually decrease until it reached 26.6°C which was the same as the room temperature. The decrease in temperature indicates the presence of small or no organic content available for microorganisms (Otaraku & Ogedengbe, 2013). Thus, the temperature for all reactors ranged between 26.6°C and 57.3°C throughout the composting period. Azura *et al.*,(2018) performed the composting of rice straw and food waste under the temperature range of 22°C to 50°C which is also similar to the findings of the current study.

3.1.2 *pH level monitoring*

pH of the compost from all reactors ranged from 4.8 to 8.0 during the whole period of composting. The results show that there was a drop in pH at the initial stage of composting which was observed on day 4, pH decreased to the range of 4.8 to 5.5; this was because the initial stage of composting involves the formation of organic acids that lower the compost pH; followed by ammonification which causes the rise in pH (Azura *et al*., 2018; Lalremruati & Devi, 2021) and it was observed from day 8 to day 12 in which the pH range rose to 7.3-8.0. This pH range is suitable for the mesophilic and thermophilic bacteria (Lalremruati & Devi, 2021); thus, it facilitates the fast decomposition of organic matter. The pH is then adjusted to near neutral (6.8-7.1) on the last days of composting (from day 15 to 20) which is the indication of complete composting and compost maturity. The decrease in pH at the initial stage of composting reflects the one reported by Sharma & Yadav, (2017) in their study about the conversion of flower waste into organic compost. However, the pH of the compost for all the reactors performed within a suitable range for microbial activities, that is between 5.5 to 8.0 as recommended by Ameen *et al*., (2016).

3.1.3 *Moisture content*

There was a variation in moisture content for all the compost bins due to the dry nature of the materials contained and quantity of faecal sludge added, the highest moisture content value was 56.4% as observed in reactor A_2R_1 contained with rice husks and faecal sludge and the minimum value was 33.4% observed in reactor B_4R_2 contained with sawdust and faecal sludge while other reactors show a moderate moisture value Based on the study done by Azura*et al*., (2018) the optimum moisture content for composting should range from 40 to 60%. However, in the current study, the water was added to the compost to adjust moisture content, it then ranged from 41.1% to 57.3% which is within the recommended range for effective material degradation.

3.2 *Biogas production*

3.2.1 *Characterization of the substrate*

The lowest value of pH was 6.75 while the highest was 7.6 for reactor A_2R_5 and A_2R_1, respectively. The pH was within the optimum range for all digesters from the fact that the optimum pH for anaerobic digestion ranges between 6 and 8 as recommended in the previous studies (Ameen*et al*., 2016). pH is the vital parameter for the growth of anaerobic bacteria that are responsible for biogas production (Paramaguru *et al*., 2017).The minimum total solids obtained was 16.4 % in reactor A_2R_1 while the highest number of total solids was 35.5% in reactor A_2R_4. This was contributed by the fact that the amount of water added to the substrate was uniform despite the fact that some of the substrates had low moisture content. Orhorhoro *et al*., (2017) reported the optimum total solids for anaerobic digestion ranging from 10-25% is suitable for the performance of methanogenic bacteria.

The concentration of COD ranged from 2030mg/L in reactor B_4R_5 to 9220mg/L in reactor A_4R_1. The higher COD in reactor A_4R_1 was contributed by the effectiveness of the performed composting in reduction of the inhibiting factors for bacterial degradation that is cellulose and lignin present in rice husks and sawdust. While the composting in reactor B_4R_5 was observed to be poor because, it didn't achieve its aim of removing cellulose and lignin content of the material as a result the biodegradable content of the material remained small, causing low COD concentration.

The highest temperature was measured on day 3 and the minimum temperature was measured on day 13 which were 31°C and 25.2°C respectively. The fluctuation in ambient temperature was due to changes in weather conditions. The favourable temperature for the anaerobic digestion process ranges from 28°C to 37°C (Schnaars, 2012). Temperature facilitate degradation of the organic matter and hence fast biogas production rate (Babaei & Shayegan, 2020).

3.2.2 *Biogas production rate*

3.2.2.1 Biogas production rates from reactors A2 (FS, 2000g; RH and SD particle size, 2mm)

The biogas production from all reactors in this cradual increase in production from day 1 to day 7. The increase in production was influenced by the presence of high organic content and fully adaptation of the bacteria to the environment (Gummert *et al.*, 2020). From day 8 to day 21 the biogas production decreased and from day 22 to 26 there was no production of gas. At this stage, there was no longer organic content or nutrients available for the functioning and growth of microorganisms (Otaraku & Ogedengbe, 2013).

The reactor A_1R_1 was observed to produce a higher volume of biogas on days 1, 2,4 and on day 5 where the production was at its peak. It produced total biogas of 11463mls for 26 days of anaerobic digestion. The high biogas production rate was influenced by suitable conditions in the reactor such as pH which was 7.6 and mesophilic temperature as well as a high concentration of organic matter in terms of COD (8840 mg/l), the reactor conditions were similar to the study done by Schwartz *et al.*, (2015) on biogas production using co-digestion of food waste and algal biomass operating under pH range of 6 to 7.8 and mesophilic temperature range between 22°C and 30.5°C. While the reactor A_2R_4 was observed to perform poorly since day 1 and produced a least total biogas of 2609mls. The poor performance is probably because it contained higher total solids,35%, which was above the recommended range (15% to 28%), as reported by Orhorhoro *et al.*, (2017), the high concentration of solids indicates the low volume of water in the material, as a result it decreases the level of microbial activity, hence cause drop in biogas production. The higher total solids provide unsuitable conditions for microbes to digest the wastes (Orhorhoro et al., 2017). The results from other reactors were found to be moderate ranging from 9000mls to 10381mls. These results can be compared with the one obtained by Length, (2011) who used millet and guinea corn husks for biogas production, he found that the highest biogas volume on day 14 (2240cm^3) and the least on day 30 (1820 cm^3).This study achieved the highest volume (2100mls) on day five of anaerobic digestion (AD) and this was because of the immediate production of the biogas at the start of experiment which was influenced by the composting performed before AD that made it easier for bacteria to digest the feedstocks (Gummert *et al.*, 2020).

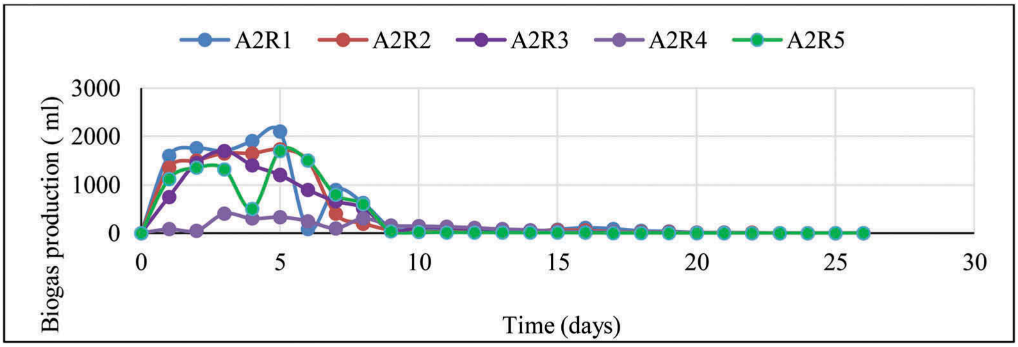

Figure 1. Biogas production rates for the reactors *A2 (FS, 2000g; RH and SD particle size, 2mm).*

3.2.2.2 Biogas production rate from reactors A4 (FS, 2000g; RH and SD particle size, 4mm)

Figure 2 shows that the biogas production rate from all reactors insting performed that reduced the concentration of cellulose and lignin that would inhibit the production of biogas (Mulyawan *et al.*, 2018). Production started decreasing from day 7 to day 10, this was possibly due to the decrease in temperature which was 27°C that is not suitable for mesophiles (Lalremruati & Devi, 2021). The production was no longer observed from day 22 to day 26 because all organic matter has already been converted to biogas. The reactor A_4R_1 was observed to produce larger quantity biogas (17202mls). This high production was influenced by the optimum pH and temperature that accelerate the microbial activity; however, this digester contained feedstock that had a higher concentration of organic matter in terms of COD. The lowest production was observed in reactor A_4R_2, possibly because of the lower concentration of organic matter (Olatunde, 2016). However, other reactors produced a moderate quantity of biogas which ranged from 1977mls to 1630mls.

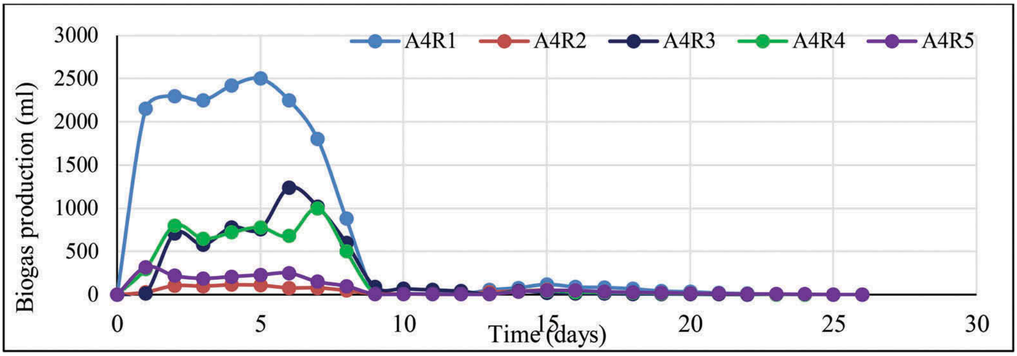

Figure 2. Biogas production rate from reactors A4 (FS, 2000g; RH and SD particle size, 4mm).

3.2.2.3 Biogas production rate from reactors B_2 (FS, 3000g; RH and SD particle size, 2mm)

The biogas production from these reactors started immediately at the beginning of the experiment, there was a high increase in production up to day 6. From day 7 the production from all reactors started to decrease (Figure 3). This might be due to the decrease in temperature from 28°C to 26°C which is not favourable for the thermophilic bacteria (Grand, 2017). The production kept decreasing up to day 23 which is the indication that the concentration of organic matter digestible by the microorganisms was decreasing Zupancic & Grilc (2012). From day 23 to 26 there was no more production of biogas since there were no more nutrients available for microorganisms (Otaraku & Ogedengbe, 2013). At this stage, all the organic content was already converted to biogas. The largest total biogas volume in this set of reactors was 9331mls, produced from the reactor B_2R_1. However, the minimum production was observed in reactor B_2R_4 which was 685mls for 26 days.

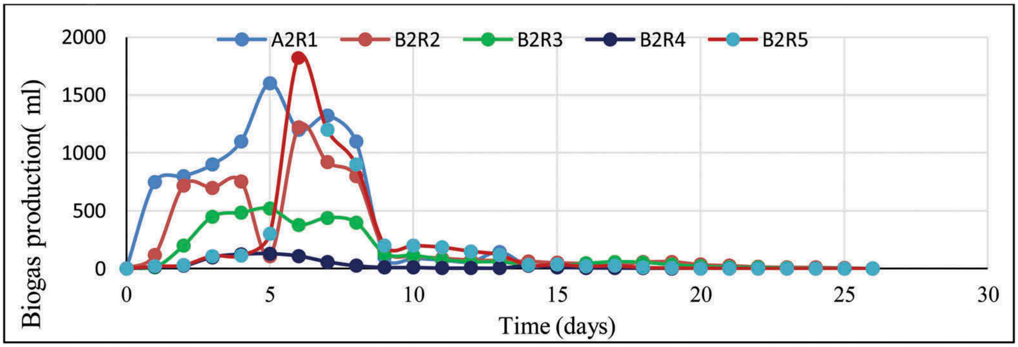

Figure 3. Biogas production rate from reactors B_2 (FS, 3000g; RH and SD particle size, 2mm).

3.2.2.4 Biogas production rate from reactors B_4 (FS, 3000g; RH and SD particle size, 4mm)

Figure 4 shows that the production of biogas started from day 1. There was high production from day 1 to day 7. From day 8 to day 19 the production started decreasing due to the reduction in organic content of the wastes by the microbes, similar decrease in production was observed by Jalil *et al*., (2021) who performed study on biogas generation from vegetable wastes where he found that the production rate was high up to 3000mls from day 1, but it abruptly decreased to 750mls on 6th day of operation. There was zero production from day 20 to 26, meaning that all organic content has already been consumed up and bacteria had no more nutrients to feed on to survive (Jalil *et al*., 2021). Reactor B_4R_1 and B_4R_5 produced larger total volumes i.e., 7620mls and 8011mls, respectively while other reactors have produced a moderate quantity of biogas ranging from 4221mls to 7779mls.

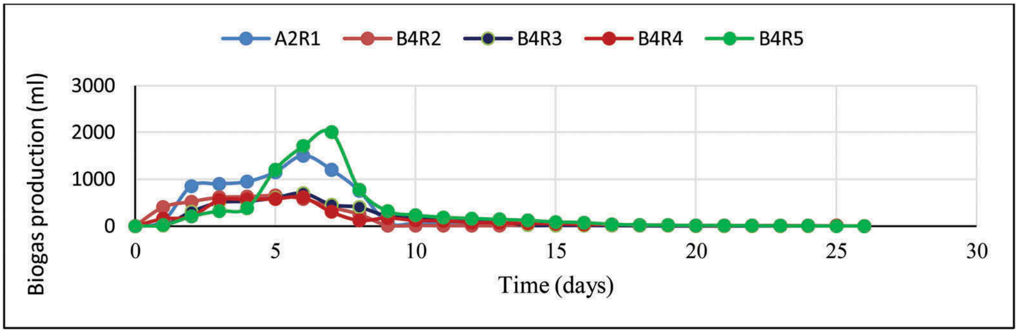

Figure 4. Biogas production rate from reactors B_4 (FS, 3000g; RH and SD particle size, 4mm).

3.3 *Overall biogas production*

It was observed that the reactor A_4R_1 produced a larger quantity of biogas, 17202mls in 26 days, followed by reactor A_2R_1 and A_2R_2 which produced 11463mls and 10381mls, respectively. The higher production in these reactors was probably influenced by co-composting performed being more effective in reduction of the inhibiting factors for anaerobic digestion such as cellulose and lignin (Mulyawan *et al*., 2018). Also, the organic matter in terms of COD for these reactors, A_4R_1, A_2R_1 and A_2R_2 was found higher that is 9220mg/l, 8840mg/l and 6200mg/l, respectively. The higher COD indicates the presence of high organic content in the material that is consumed by anaerobes producing biogas (Isni *et al*., 2016).On the other hand, reactor B_2R_4, A_4R_2, A_4R_5 and A_2R_4 produced a smaller quantity of biogas which was 685mls,1193mls, 1977mls and 2609mls, respectively. The low production in these reactors was due to the poor performance in co-composting, that is the composting was not effective in reducing cellulose and lignin contained in the material, rice husks and sawdust, hence they resist degradation by anaerobic bacteria, thus, poor production of the biogas. In addition to that, the reactors, B_2R_4, A_4R_2, A_4R_5 and A_2R_4 contained a low COD than 5020mg/l, 2240mg/l, 4250mg/l and 4300mg/l, respectively. The low COD is the indication of less organic content in the material, as a result the anaerobic bacteria dies after finishing up the degradable portion of the material, therefore this results to low production of the biogas (Isni *et al*., 2016).

The production of biogas from the other reactors was found to be moderate ranging from 3851mls to 9331mls. Thus, from the experiment it can be concluded that, the best organic waste fraction, which produced a high amount of biogas is the one with 2000g of faecal sludge and 1000g of rice husks with a 4mm particle size (reactor A_4R_1).

3.4 *Quality of the produced biogas*

The lowest amount of methane produced was 74% while the highest amount was 76%. Carbon dioxide ranged from 26% to 24%. The methane content variations for all the reactors were very close to each other. This close variation was statistically proved using single factor ANOVA which shows that there is no significant difference in biogas quality between the waste fractions from all reactors ($p>0.05$). These results can be compared with the one obtained by Mechanization, (2019) in the study of co-digestion of fecal sludge with three different materials, cow dung, mixed organic wastes and cow intestinal, reported that the methane concentration ranged from (40-70%), carbon dioxide (20-30%) and H_2S (8-10%).

3.5 *COD reductions from different waste fractions*

The COD reduction for all reactors ranged from 42.3 to 79.7%. The maximum COD removal was observed in reactor A_4R_1 which was 79.7%. While the minimum COD reduction was observed in ratio B_2R_4, which was 42.3%. The reduction of chemical oxygen demand (COD) observed in this study agreed with (Mechanization, 2019) who reported that anaerobic digestion is a feasible way of reducing COD from sludge or wastewater. Similarly, the reduction in chemical oxygen demand in this study reflects the one reported by (Wei *et al.*, 2011) who reported high COD removal from buoyant hydrothermally treated sewage sludge through an anaerobic digestion process. Furthermore, the exact same results were obtained by (Colón *et al.*, 2015) in his study about anaerobic digestion of undiluted human excreta where he found that the process is 80% efficient for COD removal in such a way it could be used as a low-cost method for effective sanitation in developing countries.

4 CONCLUSION AND RECOMMENDATIONS

The current research tried to solve environmental pollution caused by improper solid waste management by recovering some potential resources including biogas production, and the study shows that it is feasible to produce biogas from the mixture of pre-composed rice husks, sawdust and faecal sludge for all the mixing ratios. The ratio which produced the highest amount of biogas was the one that contained with 2000g of faecal sludge and 1000g of rice husks with 4mm particle size (reactor A_4R_1) produced 17202mls of biogas for 26 days i.e., 661.7mls per day and achieved the highest 80% COD removal. Therefore, the ratio 1:0 of rice husks and sawdust with 4mm particle size and 2000g of faecal sludge was found to be the optimum ratio for biogas production. However, a comparative study should be done on fresh and composted organic wastes for a different composting period to assess the influence of composting on biogas quantity and quality production.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Assessment of social sustainability in mega construction project in Tanzania: Contractors' perspectives

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ABSTRACT: Mega construction projects are considered to be large, complex, capital-intensive investment and cover a large area. However, its implementation has been affecting the environment, economic and social dimensions of sustainability. Much effort and studies have been placed on environmental and economic aspects with little attention to the social dimension. This paper aims to assess the implementation of social sustainability in Mega construction projects in Tanzania as practiced by contractors during the construction phase. The research employs a qualitative approach through the Case study method. Three ongoing mega infrastructure projects were selected as they were unique mega projects in Tanzania. A series of semi-structured interviews were conducted with project contractors and selected community members. The study reveals that a total of 29 attributes of social sustainability were implemented in Mega construction projects in Tanzania whereby, Safety, health and wellbeing and benefit-sharing were largely implemented.

Keywords: Social attributes, Social Sustainability, Mega Construction Projects, Contractors, Developing countries, Tanzania

1 INTRODUCTION

The construction industry is one of the fast-growing sectors, especially in developing countries where massive projects are currently being implemented. Apparently, many developing countries are embarking on mega construction projects such as high-speed railroads, large expressways networks, natural gas pipeline projects, large-span bridges, ports, and large hydropower projects to respond to economic development while attaining sustainable development goals. Mega construction projects are considered to be large-scale, complex and capital intensive (Erol et al, 2018; Aisheh, 2022), therefore they provide fundamental public services for social production, economic growth, and people's everyday lives. However, its nature, scale coverage, and complexity, coupled with the huge resources required have resulted in a negative impact society in all the three pillars of sustainability such as environmental, economical, and social. Literature alludes that during the implementation of Mega construction projects they experienced significant challenges and setbacks due to political, social, environmental and community problems, and therefore subjected to delays, time and cost overruns (Aiseh, 2021, Dalibi et al, 2020). The existing scholars have agreed that all the three pillars of sustainability have equal weight and should be addressed equally when assessing sustainability in construction projects (Opoku & Ahmed, 2013; Whang & Kim, 2015; Kibwami & Tuteigensii, 2016; Durdyev et al, 2018). However, the existing literature and efforts to address sustainable construction projects focused more on environmental and economic aspects

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with limited attention to the social dimension (Zulu et al 2022, Bhattacharya et al,. 2019, She et al, 2018). Noteworthy that the nature of mega construction projects involves many practitioners each bearing social sustainability responsibilities. Contractors being the major practitioners of construction activities, need to balance the expectations of different stakeholders to be socially responsible firms. However, how contractors implement social sustainability in mega construction projects is limited in the literature. This paper, therefore, aims to assess the implementation of social sustainability practices by contractors the mega construction projects in Tanzania.

2 LITERATURE REVIEW

2.1 *The theoretical concept of social sustainability*

The term 'social sustainability has its root in sustainable development with the aim to ensure a good quality of life for future generations (WCED, 1987). However, its' definition varies depending on the context and discipline-specific criteria. From a construction industry perspective, social sustainability is associated with the project's impacts on the social life system of the community in which it operates. Hill & Bowen (1997) define social sustainability as the way of improving the quality of human life, making provisions for social self-determination, capacity improvement, seeking equitable allocation of construction social cost and benefits, and empowering and participation of stakeholders. In the same line of thinking, Thounaojam & Laishram (2022) argue that construction projects need to create a successful survival of working and living of the current generation and the future generation including their health and safety wellbeing. Furthermore, Rostamnezhad & Thaheem, (2022) affirm that construction projects need to respond to the needs of people at every stage of the construction process by providing high customer satisfaction including suppliers, employees and the local community. Also, Karakhan & Gambatese (2017) state that social sustainability is "a life-enhancing process to accomplish social equality among all construction stakeholders in terms of health, education, economic welfare and other human rights.

To buttress the above discussions, social sustainability in construction is focused on the project and social interaction of stakeholders (internal and external) including their wellbeing, benefit sharing of resources, capacity building and stakeholders' empowerment and participation. However, as pointed out by Boyle et al. (2018) that the concept of social sustainability is still evolving in the research therefore, it needs to be theoretically defined and articulated by researchers who consider diverse contexts. Figure 1 presents a summary of the concept of social sustainability in construction projects.

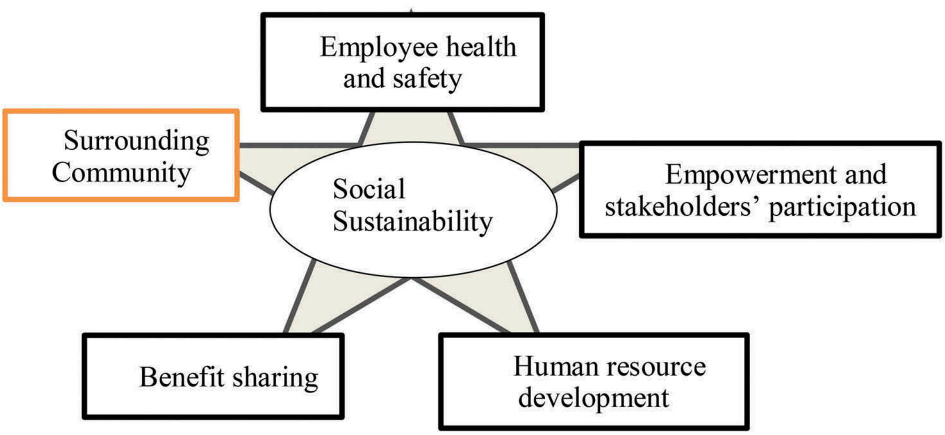

Figure 1. Concept of social sustainability in construction projects.
(source: Authors view)

2.2 *Mega construction projects and social sustainability*

Different terms have been used and interchanged in the literature when defining Mega construction projects (MCPs). These terms include complex projects, major projects, giant projects, new animals and mega-projects (Flyvbjerg, 2019, Sturup & Low, 2019. Aisheh, 2022). However, MCPs are generally defined as extremely large-scale complex projects and designed and constructed over a period of time, cover a large geographical area, and have an impact on multiple public and private stakeholders (Chen et al, 2018, Aisheh, 2022). Examples of mega projects include airports, dams, bridges, and high-speed railways, highways and tunnels, power-plant, seaports, and enormous projects for the cultural event just to mention a few.

Several studies investigated social sustainability in infrastructure development. For example, Kaminsky & Javernick (2015) reviewed the literature regarding social sustainability in infrastructure to analyze sanitation infrastructure with legitimacy theory. They focused on a particular part of social sustainability that is internal organizational participants. They also suggest that in order to recouple sanitation structure and practice for continued use and maintenance of onsite systems, designs should consider both effectiveness and compete for rational myths as the main social aspect of sustainability. Moreover, Treviño-Lozano (2022) conducted a study on framing social sustainability in infrastructure in Mexico from a Business and Human Rights Lens. She identified elements that could shape social sustainability in road infrastructure projects. Her finding reveals that the social dimension of sustainability has got both positive and negative impacts. Also, Thounaojam & Laishram (2022) reviewed the literature regarding issues in promoting sustainability in mega infrastructure projects. The finding established 19 key issues that can facilitate social sustainability in MCPs. The study has also proposed an integrated conceptual model which shows that social injustice to local communities, absence of proper institutional support and environmental destruction were the critical factors for mega construction projects. Furthermore, Shen et al. (2011) established 10 social aspects of sustainability of an infrastructure project while Leonardo et al. (2016) identified 36 social sustainability aspects assessed at each stage of the project life cycle of infrastructure. They concluded that the most social relevant aspects include, stakeholder participation, external local population, internal human resources, macrosocial action of socio-environmental activities, and macrosocial action of socioeconomic activities.

The aforementioned discussions reveals that the existing studies on social sustainability in mega infrastructure provide some social attributes for implementation of mega construction projects. However, it is noted that no consensus has yet been reached, thus attributes of social sustainability in construction projects are still evolving. According to Almahmoud & Doloi (2015) alluded that social sustainability involves subjective attributes that are influenced by complex social values and different stakeholders, therefore more research is still required in different contexts.

3 METHODOLOGY

An exploratory qualitative approach through case study was adopted to provide in depth information with the appropriate context on the social sustainability practices adopted in mega construction projects in Tanzania. According to Yin (2009), the selection of cases should reflect the most representative of the phenomenon under investigation. Nowadays, Tanzania is undergoing vast investment in mega infrastructure projects. According to the Tanzania budget report (2021/2022), there were 17 top mega projects across the country. Each project is exclusive with a unique outcome. Three cases were selected through established criteria. These criteria included on-going construction, surrounding the community and involved multiple stakeholders. The three Mega Construction projects met the criteria. The first project (P1) was the Standard Gauge Railway (SGR) construction from Dar es Salaam to Makutupora with a coverage of approximately 541km. The second project (P2) was the new Salander Bridge and its connected roads which covered a total of 6.23km. The third project (P3) was the Ubungo Interchange fly-over project connecting four (4) main roads. The total size of the interchange roads covers approximately 266 meters.

Semi-structured interview approach was used to collect data from two different sets of respondents. The first interview set was from the project stakeholders i.e. site management and workers and the second set was from the community surrounding the projects. From the project stakeholders, two site managers and two worker's representatives from each project were interviewed. From the community side, five community members from each site were interviewed. The community members were selected based on convenience. The total interviews conducted was 21. All interviews were conducted physically ranging between 7 and 20 minutes and were recorded after obtaining consent from each participant at the start of the interviews. The interview was subjected to the atlas.ti software for data management, transcribing, theme coding and analysis. According to Friese, (2019) Atlas.ti is a good tool for Qualitative Data Management, Organisation and Analysis.

4 FINDINGS AND DISCUSSIONS

4.1 *Demographic of the respondents*

The researchers began by analyzing the respondents' demographics then followed by analyzing the data taking into consideration the key themes that emerged from the interview questions. Table 1 present the demographic of the respondents. The finding reveals that the composition of the respondents was diverse with different levels of educational background and professions. Regarding gender, it was revealed that male dominated. According to Gurmu et al., (2022) social sustainability has an impact on a diverse group of stakeholders regardless of their educational background and professional status, or gender. The finding reveal that stakeholders in mega construction projects are diverse which is critical for the implementation of social sustainability.

Table 1. Demographic of the respondents.

Codes	Position of the respondent in the project	Professional	Education background	Gender
R1	Site manager P1	Engineer	Master's degree	Male
R2	Site engineer P1	Engineer	Master's degree	Male
R3	Site engineer P2	engineer	Bachelor degree	Male
R4	Project manager P2	Engineer	Master's degree	Male
R5	Site manager P3	Engineer	Bachelor degree	Male
R6	Site foreman P3	Technician	Technical	Male
R7	Worker representative P1	Technician	Diploma	Male
R8	Safety officer P3	technician	Technical	Male
R9	Worker representative P1	technician	College	Male
R10	Worker representative P2	Technician	College	Male
R11	Gang leader concrete P3	Technician	Secondary	Male
R12	Community member P1	Food vendor	Primary level	Male
R13	Community member P1	Shopkeeper	Secondary level	Female
R14	Community member P1	Hair dress saloon	Secondary level	Female
R15	Community member P1	*Mtaa* leader	Primary level	Male
R16	Community member P2	Taxi driver	Secondary level	Male
R17	Community member P2	Small businessman	Primary level	Male
R18	Community member P3	Driver	Bachelor degree	Male
R19	Community member P3	Household member	Bachelor degree	Female
R20	Community member P3	Small business man	Primary level	Male
R21	Community member P3	Taxi driver	Primary level	Male

NB: R respond number, P Project Number

4.2 *Themes from the interview*

Four themes were extracted from interview transcripts. The themes included; health, safety and security; stakeholders' participation; sharing benefit, and communication and compensation.

Since these main themes were too general, it was divided into sub-themes and then attributes for easily presentation and understanding. Kumar & Anbanandam (2019) developed a framework for the social sustainability of the freight transportation system by dividing it into three levels: enabler, criteria, and attributes. This framework was adopted to represent the findings in terms of main themes, subthemes and attributes as indicated in Table 2.

Table 2. Themes/attributes of social sustainability in Mega construction projects.

Themes	Subthemes	Social Attributes
Health and safety and wellbeing	Employee health and safety wellbeing	• Clear health and safety policy • Present of safety professionals • Provision of PPE • The procedure of reporting accidents. • Training, health and safety policy • implementation of safety barriers • signage • site layout considering safety issues as well as performing • health check-ups, • providing appropriate medical and first aid facilities for physical injuries, • communication of hazards • regular vehicle maintenance.
	Community health and safety and wellbeing	• Provision of warning boards, • adequate fencing and signal systems • clear access road • less congestion/traffic • Watering to reduce dust • efficiency and safety for pedestrians and public transport users; • improved serviceability to the community;
	Security	• Security improved
Employee empowerment and participation	Employment standards, racial and gender equality	• legal contract arrangements • standard working hours • wage payments on time • allowing different opinions from workers • Leave and rest are provided
Benefit and sharing	Business opportunity Employment creation on Contribution to the society	• increased level of business opportunities • induced business opportunities • employments opportunities to community members • contributed to various community activities such as learning facilities to schools
Communication and compensation		• Involve community/victim in the compensation process • Fair compensation

i) Employee Health, safety and wellbeing

Results show that during the construction phase the level of implementation of employee's health and safety in Mega construction projects was high. More than 15 social attributes for employee health and safety were implemented. For example, in all the three projects, there were clear health and safety policies, training on hazards on the sites, provision of all-sufficient personal protective equipment and regular vehicle maintenance. The procedures for reporting accidents were clear including the presence of safety coordinators, medical and first aid facilities, and proper site layout.

Employee safety and wellbeing is among the major components of social sustainability in construction projects during the construction phase. According to R3: [. . ..] *'Health and safety is our major concern and is our top priority activity. . ... We have a clear health and safety policy and we are implementing our Health and Safety Policy throughout all activities on this site.*

R1 [. . ..] '*We adhered to all health and safety requirements according to health and safety regulations.*

The aforementioned revealed that health and safety attributes emanated from regulations and therefore, a high level of adherence to these regulations is required. Ros-tamnezhad & Thaheeaffirm 2022) affirms that high compliance with regulations is required to ensure the health and safety wellbeing of the employees on the sites.

R2 [. . ..] *this project is an eye icon of the political, professional and community at large. Every time we receive visitors from the government and professional bodies, and OSHA, therefore, we have to adhere to all the necessary health and safety regulations.*

The finding reveals that there was a high level of compliance with health and safety regulations, and this was found to be influenced by the project's main stakeholders. The main stakeholders of mega construction projects are the government, therefore regular site visits and supervision influence compliance with health and safety regulations. This finding conforms to the study by Yang, et al., (2022) that the government plays a key role in social sustainability management because it was subject to political responsibility and also has the final decision-making power on mega construction projects.

ii) Community health and safety and wellbeing

The findings reveal that the health, safety and wellbeing of the community was moderately implemented in all three cases. The finding indicates that there was the provision of warning boards, adequate fencing and signal systems, clear access roads, reduce congestion/traffic, and watering of the sites to reduce dust, efficiency and safety for pedestrians and public transport users; improved serviceability to the community. However, it was noted that there were different opinions from different respondents across the three projects regarding to noise and dust. From the interview, it was revealed that increased level of noise and dust nuisance. R13 *said [. . .] "Since the project commenced, there has been increased level of noise in daytime and night time as an impact of project operations such as vehicles passing back and fro".*

R17 said [. . .] '*We are mostly affected by noise and dust". . . "Despite the fact that the project management have tried to reduce these nuisances such as watering the road to prevent or reduce dust, there is still a problem of dust and noise".*

The explanation from the interview revealed that dust and noise to the surrounding community are among social sustainability factors that are still a challenge in mega construction projects. Also, the issue of traffic congestion and pass routes for pedestrians in one of the sites was mentioned as a social impact of Mega construction projects R18 said [. . .] *since construction started, there have been heavy traffic jams, especially morning and evening times and affected many people traveling through these roads.*

The finding reveals that despite the positive impact of social sustainability in the community, but still some negative social impacts still prevail. Treviño-Lozano (2020) affirms that all positive and negative social sustainability in mega infrastructure should be considered. This could be the fact that the nature of mega construction projects is complex with multiple construction methods (Aisheh, 2021), therefore a careful assessment needs to be embedded.

Regarding to the security issues, it was noted that the crime level for Project 2 and 3 was reduced and as a matter of fact, the operations of the project have brought more security to the areas. As one of the respondents R20 said [. . .] *level of security has been improved, there are special guards guarding the site areas hence the area is safe.*

For Project 1, it was different where a couple of crimes were reported due to the immigration of different groups of people along the project line which lead to an increase in the number of people and circulation of money.

According to R14 said [. . .], '*there have been several cases of robbery, breaking and entering cases since the project commenced.* This finding is in line with Aisheh, (2021) that mega construction projects bring up many workforces therefore much interaction between community and workforce as well as increased circulation of money.

iii) Employment standard and participation

The finding from the interview reveals that five social attributes were implemented under employment practices and procedures. These attributes include legal contract arrangements, standard working hours, wage payments on time, allowing for different opinions from workers and lunch breaks. All the employees had employment contracts, standard working hours and lunch breaks. R7 said [. . .] '*We all have employment contacts*'. These findings are in line with the study by Allotaibe et al., (2019) which emphasizes the presence of legal contract arrangements, fair wage payment and breaks. The working contract improves job security while breaks help to reduce stress and fatigue-related injuries, therefore, offering better work-life balance, and improving the wellbeing of workers

Regarding participation, the interview reveals that there was clear information sharing among the projects' stakeholders. According to Rostamnezhad & Thaheem (2022) information sharing is one of the attributes of social sustainability. Therefore, the environment which allows information sharing in either way top-down, or bottom-up tends to increase cohesion and ensures the opinion of a stakeholder is heard and taken into account in critical decision making which will close the loop through higher satisfaction. Regarding training, the study reveals that there was not much career development in terms of opportunities for higher education in the workforce and skill development across all three projects. This could be due to fear of an increase in costs of the project by the contractor as suggested by Aisheh (2021).

iv) Benefit-sharing

Finding from the interview divulges that there was an increased level of business opportunities and induced business opportunities in all three cases. To mention a few; food and soft drinks, real estate (house renting for shelter) so that workers can live in the nearby sites, clothing, sim banking, transportation and the likes.

R12 said [. . .] *I have witnessed an increased number of customers due to this project especially during the breakfast and lunch hours. My revenue has doubled*' The finding is in line with various studies such as Thounaojam & Laishram (2021), Allotaibe et al., (2019) and Aisheh, (2021) who found that the increased level of project business activities is a result of an increase in the interaction of people from the projects. From the interview, it was further revealed that the contractors also provide employment to the members of communities and make other contributions to community services. In project one for example the contractor provides employment for more than 4000 people in different departments of the project from the extraction of materials, excavations, supply of water, food, security, drivers, construction activities, and all other related work.

This finding conceals that both direct and indirect employment was created through the integration of local people into the construction of projects and through creating a demand for supplies such as food, clothes and beverages. Direct and indirect employment impact their social inclusion in the market, and can also boost local economies. Furthermore, the contractors affirm that they contributed towards many social activities in the community such as hospitals by assisting by providing cars during children's vaccine in the village, helping the orphans with food and other basic needs, contributing to education by donating food to students.

R1 said [. . .] "*We normally contribute to community activities such as assistance in the vaccine for children, education and inviting the village authorities to our ceremonies as a way of showing cooperation and appreciation.*

v) Communication and compensation

The finding reveals that compensation due to the loss of properties such as land and buildings to make way for the new infrastructures portrays a different pattern in all three cases. On the issue of project 1, there was a great need for compensation due to the fact that many people lost their land and buildings to give way to the new infrastructures. According to the management, a total of 2892 families and land owners have been compensated and others are still being compensated. As for Project 2, it was a little different as the loss was on government-owned properties. For the issue of Project 3, there was no compensation made. From the interview, it was revealed that not all victims were satisfied with the compensation process. There were a lot of complaints which also affect the progress of the work.

Rostamnezhad & Thaheem (2022) alluded that compensation is among the social dimension in infrastructure development, therefore, reasonable compensation and relocation plan/strategies with clear communication are required. Emphasis more, R15 said, [. . .] *The number of people in my street was compensated to pave way for the projects. We were all involved in the process and some members agreed on the compensation while some had many complains.*

The finding is in line with what Rostamnezhad & Thaheem (2022) said that the issue of compensation is challenging especially in developing countries. Therefore, the favorable and transparent process of the resettlement plan, like locations, and resettlement costs, needs to be thoroughly evaluated by decision-makers and the victims to reach a consensus on what standards are reasonable or not. Therefore proper and diversified communication channels are needed to allow dialogue in a less racial manner.

5 CONCLUSION

This research employs a qualitative approach to explore the social attributes for social sustainability of mega construction projects as practiced by contractors during the construction phase. The study reveals that 29 social attributes which fall under 4 major categories of social sustainability were implemented by contractors in mega construction projects. These categories include health, safety and security; stakeholders' participation; sharing benefit, and communication and compensation. Within the four categories, it was revealed that health and safety were largely implemented, whereby, 20 social attributes prevailed for both employee and community populations. This could be the fact that health and safety in construction is a legal requirement, therefore their compliance was influenced by legislation and instigation by top management. Mega construction projects are complex with large interaction of many stakeholders with vast investments, therefore, drawing attention to the public. Regular site visits, clear supervision and clear regulations with enforcement mechanisms influence the implementation of social sustainability in construction sites. Therefore, there is a need to review the existing regulations to ensure they cover all aspects of social sustainability. Direct and indirect employment was created by contractors in the mega projects as well as participation in social activities within the community as part of benefit sharing. This enhances relationships and boosts the community economy. Despite the good contribution of social attributes, few negative social attributes prevailed. There were increased noise and dust as well as a level of crime in the community. The proper strategies for reducing noise and dust need to be reinforced in mega construction projects. The mega construction project also tends to re-allocate community members therefore, transparent and diverse communication is required to reach a consensus on compensation rate. This study contributes to the board of knowledge in the field of construction management in mega construction projects. The attributes revealed in this study will help contractors to make considerations in their planning phase. Both social attributes have cost implications therefore clear assessment is required. This study is limited to only three cases in the same geographical area, therefore recommends more research in a different context.

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*Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)*

Climate resilient flexible pavement incorporating fine copper slag and pen 35/50 bitumen binder

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ABSTRACT: Rising temperatures due to climate change and increasing road traffic loads accelerate pavement distress triggering earlier-than-planned maintenance costs. Climate resilient and sustainable flexible pavements can be constructed using non-conventional materials like copper slag (CS). This study investigated partial replacement of fine natural stone aggregate (NSA) with CS in hot mix asphalt (HMA) made with pen 35/50 bitumen, a semi-hard binder not commonly used in hot climates. Weight proportions of 15%, 20%, 25% and 30% of CS replacing fine NSA, produced HMA with decreased optimum binder content and improved Marshall and strength properties. These results indicate enhanced resistance of the CS-pen 35/50 bituminous mixtures against pavement rutting and deformation - the desired performance characteristics of climate resilient flexible pavements in hot climates. Optimal proportions of 20% to 25% CS replacing NSA in the CS-pen 35/50 HMA was observed. Field performance evaluation of this CS-pen 35/50 HMA is recommended.

Keywords: Copper slag, flexible pavement, climate resilient, Marshall properties, 35/50 bitumen binder

1 INTRODUCTION

Rehabilitation of existing roads and construction of new ones require approximately 15,000 tons of natural aggregate in a bituminous road surface layer per kilometer (Mallick et al., 2013). This points to exploitation of huge amounts of non-renewable resources in the development and maintenance of road infrastructure required for the sustenance of many countries' economies.

Efforts to conserve non-renewable resources and mitigate negative environmental impacts related to exploiting natural resources include research, investment and various initiatives in sustainable road design and construction practices. The Zambian government, for example, has embarked on an initiative called the Output and Performance Based Road Contracting (OPRC) in which sustainability is a key factor (Zulu et al., 2020). Driving this sustainability forward partly requires innovatively incorporating appropriate alternative materials in road design and construction. One such alternative material is copper slag (CS), a by-product of copper production. Continuous disposal of CS at slag dump sites poses potential environmental hazards of air, water and heavy metal pollution, reduced useful land availability and ugly landscape outlook (aesthetics). However, riding on some literature that indicate that CS is non-hazardous (Alter, 2005, Das et al., 1983, Lye et al., 2015, Sharma et al., 2020), utilising CS in construction would reduce the aforementioned possible environmental pollution.

Approximately 2.2 tons of CS is generated per every ton of copper produced (Raposeiras et al., 2016, Reddy et al., 2019, Sankarlal et al., 2017, Sharma et al., 2020,). Global generation of CS is

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estimated between 24 to 38 million tons per annum (Gorai et al., 2003, Lye et al., 2015). In Zambia, the government is pushing for increased copper production from the current 800,000 to over 3 million tons per annum by 2031. This is likely to translate into an annual generation of about 6.6 million tons of CS in Zambia in the near future. These high amounts of CS can be potentially utilised as aggregate for construction of flexible pavements.

Various studies (Pundhir et al., 2005, Raposeiras et al., 2016, Ravishankar et al., 2021, Sankarlal et al., 2017) have shown that physical properties of CS include rough surface texture and angular shape which provide effective interlocking and friction properties. Gorai et al. (2003) further contend that the excellent soundness, good abrasion resistance and high friction angle of air cooled and granulate CS makes this material suitable in hot mixes for flexible pavements.

Climate change is linked to climate stressors that can cause fast deterioration of a road pavement. Among these is temperature, which, when compared to other climate stressors such as precipitation and groundwater has greater detrimental effect on the performance of flexible pavements (Qiao et al., 2020). Accordingly, flexible pavements are very susceptible to deformation under high temperatures, leading to major distresses such as rutting (Ziari et al., 2016). Furthermore, high temperatures tend to reduce the stiffness of bituminous materials, thus limiting the stress-strain response and further reducing the load carrying ability of the pavements.

Global temperatures are projected to rise by 1.5°C in the next 20 years due to climate change. (Intergovernmental Panel on Climate Change (IPCC), 2021). This, coupled with the ever increasing traffic loads on roads, will very likely accelerate pavement distress and trigger earlier-than-planned pavement maintenance and rehabilitation, thereby upsetting road agencies' maintenance budgets. Adapting flexible pavement design, by partly aiming at reducing road pavements' vulnerability to climate stressors is therefore a key consideration towards realising climate resilient flexible pavements. In this regard, the choice of an asphalt/bitumen binder and other road pavement constituent materials can help in overcoming the aforementioned climatic as well as traffic-related factors that adversely impact flexible pavements' performance.

Incorporating CS, a non-conventional aggregate in bituminous mixtures has been observed to enhance properties of these mixtures. Reddy et al. (2019) observed that bituminous mixtures containing CS as aggregates exhibited high fatigue and rutting resistance at high temperatures compared to conventional mixes. Ravishankar et al. (2021), noted that CS used as mineral filler in bituminous concrete made with penetration grade 50/70 (pen 50/70) bitumen binder provided effective interlocking and friction in the bituminous concrete mixtures, resulting in higher Marshall stability (MS), decrease in optimum bitumen content (OBC), increase in bulk density, and improved indirect tensile strength (ITS) values compared to conventional mixtures.

Sharma et al. (2020) studied the suitability of using CS as partial replacement of natural fine aggregate in dense bituminous macadam (DBM) made with pen 50/70 bitumen binder. Various tests on DBM containing 0% to 25% CS showed that substituting 15% of natural aggregates with CS enhanced the strength and durability of DBM. An investigation by Ziari et al. (2016) on the potential use of CS in warm-mix asphalt concrete made with pen 60/70 bitumen, showed that replacing up to 20% by weight of total aggregate with CS enhanced the MS, the Marshall Quotient (MQ) and the rutting performance of the mixture. Pundhir et al. (2005) showed that substituting up to 30% of fine aggregate with fine CS aggregate in bituminous mixtures made with pen 60/70 bitumen binder improved the interlocking, volumetric and mechanical properties of the mixtures. Hassan and Al-Jabri (2011) incorporated up to 40% CS in a Marshall-mix design made with pen 60/70 bitumen binder. The study showed that the tensile strength ratio (TSR) results for mixtures with CS were higher than those for the control mix and concluded that CS was a potentially good material for use as an aggregate in asphalt mixtures.

Excessive moisture ingress, e.g. due to a combination of high rainfall and high vehicular traffic, can cause high pore pressure build up in bituminous layers. This could lead to accelerated stripping/raveling and ultimately to complete aggregate-bitumen adhesion disruption in flexible pavements (Qiao et al., 2020). Incorporating CS in bituminous mixtures has indicated resistance to moisture ingress in the mixtures and hence reduced moisture-induced damage to flexible pavements. The resistance to moisture ingress is attributed to the high silica (SiO_2) content in CS (Ravishankar et al., 2021, Sudarshan and Suresh, 2021). Reducing moisture-induced damage in this way can be of considerable benefit in situations of increased moisture conditions arising from increased rainfall due to climate change effects.

The literature cited in this section show that incorporating CS in bituminous mixes improves the MS, ITS, TSR as well as the interlocking and friction properties of the mixtures. It also shows potential to reduce moisture-induced damage in bituminous pavements. It is, however, noted that most of the studies on the effects of incorporating CS in flexible pavements have been done on bituminous mixtures that are made from bitumen binders with penetration grade range of 50 to 70. It is further noted that pen 60/70 bitumen, a soft binder, is a commonly used binder, even in tropical and sub-tropical climates where temperatures are high most of the year.

With projected rise in temperatures due to climate change, the frequently observed rutting and other pavement distresses in tropical and sub-tropical climates will continue to manifest. Achieving climate resilient flexible pavements with soft bitumen binders in these climates is thus an arduous undertaking. Consequently, increased cost burden on pavement maintenance, high vehicle operating costs and increase in road traffic accidents will persist in these climates.

In a bid to deliver climate resilient flexible pavements in view of the climate-change-induced rising temperatures, pen 35/50 bitumen, a semi-hard binder, was used for pavement construction on a recent Turnpike/Kafue-Mazabuka road rehabilitation project in Zambia. This is the bitumen binder grade that has been used in the research presented in this paper.

There is scarce literature on the effects of using semi-hard binders such as pen 35/50 bitumen on the performance and durability of pavements in warm and hot climates. Furthermore, various literature cited in the foregoing discussion indicate that research on the behaviour of bituminous mixtures made with semi-hard and hard binders incorporating CS is extremely rare. The research presented in this paper sought to contribute to bridging these knowledge gaps.

2 MATERIALS AND METHODS

2.1 *Materials*

The CS used in this study was obtained from Mopani Copper Mines, Mufulira district in Zambia. It consisted of particles with a maximum size of 4.75mm.

The natural stone aggregate (NSA) with particle sizes between 0 and 14 mm was obtained from a crusher plant in Mazabuka district in Zambia. Aggregates passing the 4.75 mm sieve but retained on 75 µm sieve were categorized as fine aggregate while those of larger size were considered coarse as recommended by the Southern African Bitumen Association (SABITA) (SABITA, 2020).

Pen 35/50 bitumen was used as binder. Quarry dust was used as inert filler material. A general purpose Portland limestone cement, grade 32.5 N/mm^2, was used as an active filler (1% by weight of total aggregate.

2.2 *Chemical and physical tests on aggregates and bitumen*

Chemical composition of the CS was done using a Scanning Electron Microscope (SEM) with Energy Dispersive X-Ray Spectroscopy (EDS) analysis technique. Physical tests on aggregates were determine according to the following testing standards**:** Aggregate Crushing Value (ACV) (Technical Methods for Highways (TMH) 1 Method B1); 10% Fines Value (10%FV) (Dry) (BS 812-111:1990); Flakiness Index (FI) (BS 812-105.1: 1989); Specific Gravity (G_s) and Water Absorption (WA) (AASHTO T84-95).

Physical properties of bitumen were determined according to the following testing standards: Penetration at 25°C and Softening points (AASHTO T53-96); Dynamic viscosity at 60° C and at 135°C (ASTM D4402); Specific gravity (AASHTO T-209)

2.3 *Mix samples preparation and tests*

Mixes of the CS and NSA were prepared in such a manner that their particle size gradation (PSG) met the criteria of the Fuller and Thomson maximum density grading curve. This PSG ensures maximum density of compacted road aggregate material (Kambole et al., 2021), enabling the desired aggregate packing that ensures that acceptable performance characteristics of the resulting mixtures are achieved.

The Fuller and Thomson maximum density gradation equation (Equation 1) was used to calculate the constituents of PSG.

$$P_i = 100\left(\frac{d_i}{D}\right)^{0.45} \tag{1}$$

where: P_i = is the percentage passing the i^{th} sieve; d_i = is the size aperture of the i^{th} sieve; and D = is the maximum aggregate size.

The 0.45 exponent value adjusts the fineness and coarseness for maximum particle density

The constituted Fuller PSGs with varying percentages of CS as a replacements for fine NSA were then used to make batches of hot mix asphalt (HMA), using pen 35/50 bitumen binder. The replacements were done at CS proportions of 15%, 20%, 25% and 30% of the weight of fine NSA.

After evaluating the OBCs for mixtures with the aforementioned CS proportions, the compacted bituminous mixtures were subjected to MS tests for stability and flow according to TMH 1 Method C2. Other properties evaluated were: the voids in mineral aggregate (VMA), i.e., the air voids between aggregates in the compacted mixture, the air voids (VA), i.e. the small spaces of air between the coated aggregate particles in the final compacted mixture expressed as a percentage of the total volume of the mixture and the voids filled with bitumen (VFB), i.e., the percentage of VMA filled with binder. The Indirect tensile strength (ITS) test was also done according to ASTM D6931 (2012). The ITS was further used to evaluate the E-modulus of the samples using Equation 2 as provided in Ministry of Works (2000).

$$E_{Mod} = (6.1\ S_t) + 100 \quad (MPa) \tag{2}$$

where S_t = indirect tensile strength.

3 RESULTS AND DISCUSSION

3.1 *Chemical properties of CS*

The chemical compounds in CS, based on the Energy Dispersive X-Ray Spectroscopy (EDS) analysis, are presented in Table 1. The major chemical compounds observed are Fe_3O_4 and SiO_2. The high iron content contributes to the higher specific gravity of CS compared to that of NSA as can be observed in Table 2.

Table 1. Chemical composition of CS.

Chemical Compound	Fe_3O_4	SiO_2	MgO	Cu	Na_2O	Al_2O_3	CaO	K_2O	S	*Others*
Content (%)	38.0	30.7	2.9	0.9	0.4	4.9	4.0	1.7	1.2	11.5

3.2 *Physical properties of aggregates used in the HMA*

Results presented in Table 2 show that the ACV, 10% FV and FI of the NSA met the specification recommended in the Overseas Road Note (ORN) 31 (Transport Research Laboratory, 1993) as well as the Southern Africa Transport and Communication Commission (SATCC)

(SATCC, 1998). Further, the WA of the fine and coarse NSA and that of CS also met the requirements of ORN 31 and SATCC.

Table 2. Aggregates test results.

Property	Coarse NSA	Fine NSA	CS Aggregate	SATCC Specification*
ACV (%)	20	-	-	< 25
10% FV (Dry) (KN)	210	-	-	> 180
FI (%)	14.7	-	-	< 35%
G_s	2.711	2.657	3.629	-
WA (%)	0.5	0.85	0.63	< 1.5%

* Also recommended in ORN 31

Figure 1 presents Fuller maximum density PSG curves of CS combined with NSA and plotted in relation to the upper and lower grading limits for aggregate with nominal maximum particle size of 14 mm, as recommended by SABITA (2020). They represent aggregate size gradings that produce the desired aggregate packing for the required performance characteristics of the resulting HMA.

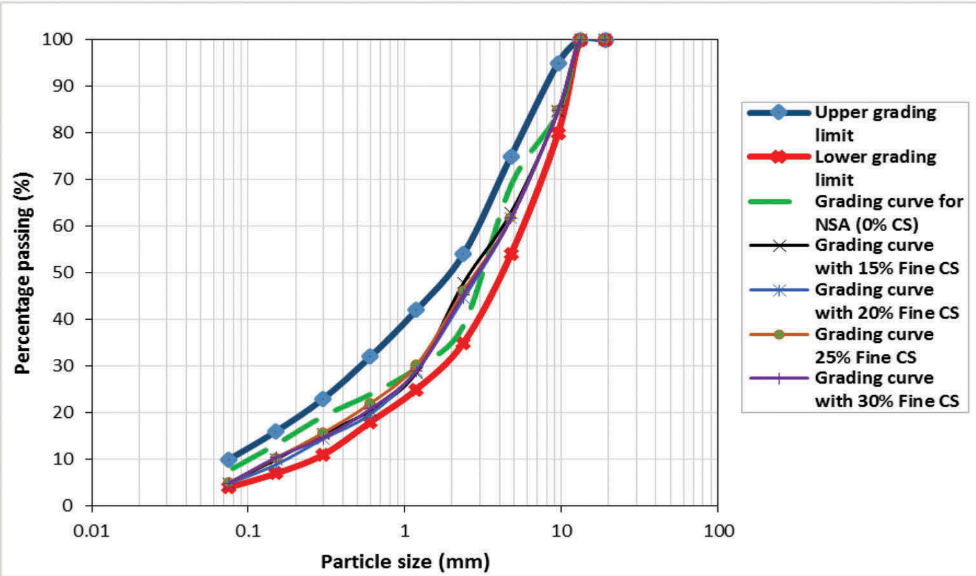

Figure 1. Grading curves for different proportions of CS combined with NSA in relation to the upper and lower grading limits for aggregate with nominal maximum particle size of 14 mm.

3.3 *Physical properties of 35/50 bitumen binder*

Tests results in Table 3 indicate that the evaluated physical properties of pen 35/50 bitumen met the requirements of the South African national Standards (SANS) specification (SANS 4001-BT1, 2012), a specification also applicable to flexible pavement design in Zambia.

3.4 *Marshall properties tests results*

The selected OBC in a mix design for HMA should lead to a balance among all of the desired Marshall properties, i.e. MS, VFB, VMA and VA. The OBC is evaluated as the average

Table 3. Physical properties of pen 35/50 bitumen binder.

Physical property	Test results	Specification*
Penetration at 25°C (dmm)	42.6	35 - 50
Softening point (°C)	60.05	49 - 59
Dynamic viscosity at 60°C (Pa.s)	282.5	220 - 400
Dynamic viscosity at 135°C (Pa.s)	0.362	0.22 - 0.50
Specific gravity	1.03	-

* The specifications for pen 35/50 bitumen according to SANS 4001-BT1 2012

obtained from binder contents corresponding to 4% air voids, peak bulk density and peak stability (SABITA, 2020). These results are presented in Table 4.

Table 4. Average OBCs in HMA with different amounts of CS.

	HMA				
	0% CS	15% CS	20% CS	25% CS	30% CS
Average binder content at 4% Air Voids	4.8	4.45	4.45	4.55	4.65
Bulk Specific Gravity	2.40	2.45	2.46	2.47	2.47
Peak Stability (kN)	4.9	4.58	4.9	4.65	4.65
OBC (%)	4.9	4.61	4.63	4.7	4.73

The OBC decreased from 4.9% at 0% CS to 4.61% at 15% CS but thereafter steadily increased up to 4.73% at 30% CS. It is further worth noting that the OBCs for all mixtures with CS were lower than the OBC for the 0% CS mixture. These results and observations can be attributed to reduction in voids after incorporating CS in the HMA mixture. This further indicates an overall reduction in bitumen consumption when CS is incorporated in bituminous mixtures, with possible cost savings.

Other Marshall properties determined from the OBC values of different HMA mixes, are presented in Table 5. These properties are compared with the requirements for HMA mixes specified in SATCC (1998), and those specified on a Zambian project where pen 35/50 bitumen was used.

The results indicate a drop in MS and MF values after incorporating CS in the mixes, when compared with the values for the 0% CS mixture. The generally observed reduction in MF values in mixes with CS content compared to the MF from the 0% CS mix is an indication of reduced bitumen bleeding potential. This is beneficial in hot climates where this phenomenon is prevalent. All the MF results were within both the SATCC and Zambian project-specific limits.

It is noted that the MS results exceeded the SATCC specification limits but were within the Zambian project-specific limits. The MQ, a ratio of MS to MF, points to the state of stiffness of mixtures. The increase in MQ with increase in CS implies that CS has the effect of enhancing strength and resistance against permanent deformation and rutting in HMA. These are desired performance characteristics of climate resilient flexible pavements. Similar results were obtained by Ziari et al., (2016) when studying the effects of incorporating CS in warm mix asphalt using a soft bitumen binder.

The VA results were within the specified limits of 3 - 6%. Noticeable increase in VA in mixtures with more than 20% CS content can be attributed to angularity of CS which, when combined with natural aggregate tends to induce changes in particle packing that may cause slight increase in void space and hence higher VA as argued by Dhir et al. (2017). Increased VA can be beneficial for increased stability and prevention of rutting beyond the critical compaction level (Mahan, 2013).

Table 5. Results of OBCs and Marshall properties at varying CS proportions compared with SATTC and the Zambian (project specific) specifications.

	OBCs and Marshall properties at varying CS proportions					Specification Limits		
Property	Control Mix (0% CS)	15% CS	20% CS	25% CS	30% CS	SATCC*	Zambian (Project-Specific)†	ORN 31#
OBC (%)	4.9	4.61	4.68	4.7	4.73			
MS (kN)	15.8	13	14.5	13.8	13.7	3.5 - 12.5	9 - 18	>9
Marshall Flow (MF) (mm)	3.25	2.7	2.8	2.66	2.55	2 - 4	2 - 4	>2
MQ = (MS/MF) (kN/mm)	4.86	4.82	5.18	5.19	5.37	2 - 3.5	>2.5	-
VMA (%)	15.1	15.4	15.9	16.7	17.5	-	>15	>15
VFB (%)	72.5	78	80	79	77	-	65 - 75	-
VA (%)	4.0	3.4	3.2	3.5	4.0	3 - 6	3 - 6	3 - 5
Filler Bitumen Ratio	1	1	1	1	1	1 - 1.5	1 - 1.5	-

* Extracted from Table 4203/1 (SATCC, 1998)

† Modified values from Table 4203/1 (SATCC, 1998) to comply with pen 35/50 bitumen used on the Zambia's Kafue

– Mazabuka Road Project. The modification was in view of the increase in traffic experienced on this road and the observed increased hot climatic conditions.

\# Specification for 'severe sites' conditions related to slow moving heavy traffic (Transport Research Laboratory, 1993).

The VMA results increased with increase in CS and was well above the minimum limit of 15% as specified under the Zambian project specific requirements and the ORN 31 (Table 5). The VFB increased up to the 20% CS mix but steadily decreased in mixtures with more than 20% CS content (Figure 2(a)). This could be attributed to the lower WA characteristic of CS (implying lower void ratio) compared to the WA of NSA. The VFB is a measure of durability and has a significant correlation with the density of mixes in that if VFB is too low (e.g. lower than the specified limit, 65% in the Zambian project-specific situation), then there is little bitumen to provide the required durability (Mugume and Kakoto, 2020).

In this study, much higher VFB values were observed, compared to those specified for the Zambia project-specific requirement, implying that more voids were filled with more binder than required for durability. The increased amount of effective binder, in this regard, could lead to bleeding and lower stiffness of the mixture (John et al., 2021). An adjustment of the bitumen content to ensure that the VFB remains between the 65 and 75% limits would be required in this case, especially for heavily trafficked flexible pavements.

3.5 *Indirect Tensile Strength (ITS) and modulus of elasticity (E-Modulus) Results*

Figure 2(b) shows the ITS results and the evaluated E-Modulus values of bituminous mixtures with different CS content at 4.9% bitumen content, the OBC for the mix with 0% CS content. This binder content was used as a basis to evaluate the effect of different constituents of CS on ITS and E-Modulus of the bituminous mixtures.

The general trend of the results was that increase in CS content resulted in increased ITS and E-Modulus values. A remarkable increase in E-Modulus of almost 31% was recorded at 30% CS content compared with the E-Modulus recorded at 0% CS. This can be attributed to increased interlock in the CS-aggregate mix bound by a semi-hard bitumen. Increase in these parameters imply higher strength and improved resistance to deformation. This should lead to reduced rutting and shoving in a flexible pavement, a desired performance outcome for climate resilient flexible pavements. Similar results, using a soft bitumen binder were obtained by Sharma et al., (2020).

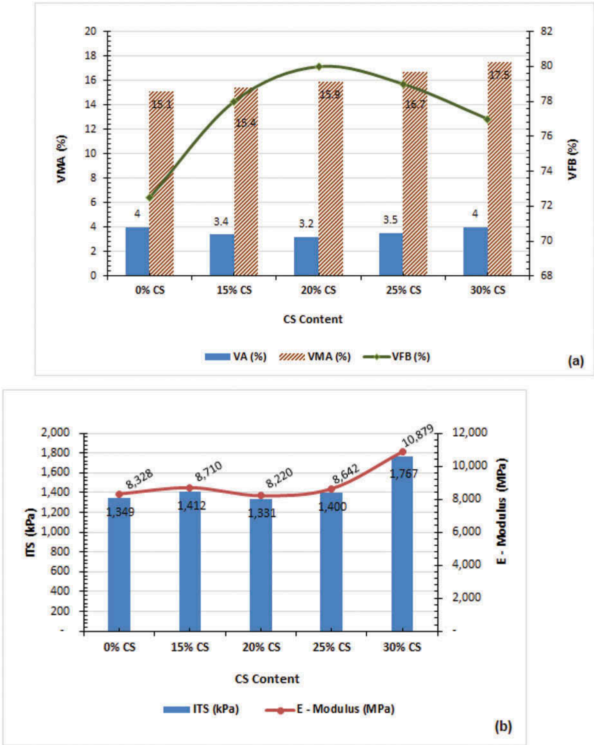

Figure 2. (a) Changes in VA, VMA and VFB in relation to CS content; (b) ITS and E-Modulus results of bituminous mixtures with different CS content at OBC of 4.9%.

4 CONCLUSIONS

This study shows promising potential of utilising CS as partial replacement for fine NSA in HMA using pen 35/50 bitumen for climate resilient flexible pavements. Increase in CS content resulted in reduced OBC, which could translate to bitumen cost savings. The MF and VA values of HMA incorporating CS were, respectively, within the 2 - 4 mm and the 3 - 6 % limits, specified by the SATCC and a road project in Zambia where pen 35/50 bitumen was used. The VMA results were well above the minimum 15% specified on a Zambian road project and the ORN 31. Reduced MF with increase in CS content implies reduced bitumen bleeding potential in HMA. Increase in MQ, ITS and E-modulus with increase in CS contents indicate enhanced strength and resistance to permanent deformation and rutting in HMA. These are desired performance characteristics for climate resilient flexible pavements in hot climates. The results further indicate that CS can be optimally incorporated at between 20% and 25% CS replacement of fine NSA in surfacing mixes for flexible pavements.

The results presented in this paper are based on laboratory investigations. Field investigations of the performance of HMA made with pen 35/50 bitumen and incorporating CS are therefore recommended.

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*Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)*

Sustainable constructions and cases of high-rise buildings collapse in Nigeria

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ABSTRACT: High-rise residential and commercial development in developing countries like Nigeria has been spurred by both the rapid growth of the population and the pressing need to protect the country's limited land supply in areas of commercial development. However, recent years have seen an increase in the number of building collapses in Nigeria, which is a cause for concern. This study uses statistical method on historical data to highlight the scenarios of the collapse of high-rise buildings in Nigeria and drawing a relationship with it to sustainable construction. According to this study, Nigerian high rises have a low rate of collapse despite the country's high rate of collapse, but the number of fatalities in the collapse of these structures is alarming. The high death toll associated with these collapses is a negative indicator for achieving the Sustainable Development Goals of the United Nations (SDGs).

Keywords: Building Collapse, High-rise Buildings, Casualty Rate, Failure Rate, SDGs

1 INTRODUCTION

Sustainability, as a concept has gained increased importance in the construction industry over the past few decades. A large contributor to this is the United Nations World Commission on Environment and Development who facilitated an awareness concerning the urgency to lessen the detrimental effect of development and urbanization activities on the society and environment, having particular emphasis and focus on raising developing countries (Dania, 2016; WCED, 1987). In general, sustainability in construction refers to the implementation of sustainability concepts in construction practices or techniques (Esezobor, 2016). Sustainable construction (SC) can be termed to be the act of creating and managing a healthy built environment by the efficient utilization of ecological principles and resources (Kibert, 2012).

Every construction activity basically entails combustion of fossil fuels, release of CO_2, methane, & other by-products which causes pollution to the environment as well as the loss of natural ecosystems (Toriola-Coker et al., 2021). The construction sector has been demonstrated to have negative environmental consequences attributed to waste creation, depletion of energy and water, and a variety of other factors (Aigbavboa et al., 2017). Construction operations have a huge impact on global climate change and pose several additional environmental risks. According to the United Nations Environment Programme, the construction sector accounts for the release of around one-third of global greenhouse gas and consumes considerable amounts of non-renewable natural resources

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(Esezobor, 2016). In addition, construction activity is said to consume half of the resources utilized by man, of which 50% of the world's fossil fuel has been utilized to serve buildings, 37% of the world's total energy is used in construction works, and roughly 6500 hectares of rural area has been converted to urban territory (He, 2019).

The quest to assuage the negative and detrimental effects of human activities on the environment brought about the concept of sustainability (Akinshipe et al., 2019). According to (Anigbogu & Kolawole, 2005), the best approach to ensure that the ecosystem is preserved is to avoid any type of building activity, which is nearly impossible. The only rational thing to do is to engage in activities that counteract the negative environmental impacts of development (Dahiru et al., 2014). As a result, the notion of sustainable construction has emerged, which incorporates the construction, design, operation, maintenance, and management of a structure (Akinshipe et al., 2019). Conservation of land, conservation of energy, conservation of material, reducing pollution, and stormwater retention, as described by Nwokoro, are five essential strategies that may be used to accomplish sustainable construction (Nwokoro & Onukwube, 2011).

Many countries' pushes for sustainable building have been fuelled by population growth and excessive demand for buildings and infrastructure. High-rise buildings are becoming a noticeable feature in major cities of economic or political importance due to the ever-increasing need for accommodations and gradual disappearance of buildable land in major urban areas of the world (Ede, 2014).

Populations are moving to densely populated metropolitan areas because of global urbanization. As a result, there is an increased adoption of high-rise buildings that might have disproportionately negative effects from exposure to extreme weather. These slender structures are extremely vulnerable to wind-induced motion. In designing high-rise buildings, structural engineers are faced with the problem of working toward the most effective and cost-effective design solutions while guaranteeing structural safety, serviceability for intended use, and liveability for inhabitants during its design lifetime (Ding & Kareem, 2020).

More high-rise structures with unusual designs have been steadily constructed because of advancements in construction techniques, materials, and technology. Due to the increased susceptibility of high-rise structures to wind excitations, optimizing the shape of the cross-section is proposed to increase wind resistance (Zheng et al., 2018). When a building component cannot support the loads that it was intended to support, the structure collapses. When one or more components of a structure are unable to effectively carry out its original purpose due to the dysfunction of the constituent materials, the building is considered to have failed and collapsed (Odeyemi et al., 2019).

Most often in developing nations, construction of buildings results in life, health, and resource losses. These losses start with construction health and safety on site and extend to the post construction phase (Al-Khaburi & Amoudi, 2018). In future growth, vertical building construction has benefits for space use, plant space preservation, etc., but these benefits also have a cost for various developing nations like Nigeria. The collapse of multi-storey buildings has become a persistent problem for the Nigerian construction sector which has had a substantial effect over many years (Sutherland, 2017). In Nigeria, about 170 buildings are estimated to have collapsed between 1971 and 2016, resulting in the deaths of over 1500 people (Hamma-adama et al., 2020).

Over the years, the quality of life has improved, resulting in significant technical improvements. Improved methods, more resilient materials, improved construction equipment, and more sophisticated construction expertise are available today. Despite all the technological advancements, there are still instances of building collapse in many nations, but they are more common in developing nations like Nigeria. Natural disasters or man-made events such as bomb explosion like the one at World Trade Centre are the main causes of collapse in affluent nations. However, poor supervision, poor quality or substandard materials, a disregard for standards and regulations, a lack of qualified professionals, overloading, a lack of geotechnical or subsoil investigations, poor construction practices, unlawful approval, incorrect demolition procedures, a lack of maintenance, among many other factors, are frequently to blame for collapse in developing nations (Ajufoh, Gumau, & Inusa, 2014; Akpabot, Ede, Olofinnade, & Bamigboye, 2018; Ede, 2010; Ede, Olofinnade, & Awoyera, 2018; Adetunji, Oyeleye, & Akindele, 2018; Odeyemi et al., 2019; Oyegbile, Nguyen Tat, & Olutoge, 2012; Windapo & Rotimi, 2012). This paper aims to explore the cases of the collapse of high-rise buildings in Nigeria and seek a relationship with sustainable construction practices.

2 OVERVIEW OF HIGH-RISE BUILDINGS

The classification of high-rise buildings varies depending on the environment in question. It will be simple to categorize a four-story structure surrounded by bungalows as a high-rise building in the neighbourhood, and this claim won't be challenged (Ubani, 2021). Bungale contends that high-rise buildings can't be categorised in terms of a certain number of floors or storey height; rather, the line separating them should be where the structure's design crosses over from the statics to structural dynamics fields (Bungale & Taranath, 2010; Taranath, 1988). A building is a high rise if it is much high-riseer than the nearby structures or if its proportions are thin enough to create the impression of a high-rise building, according to the Council on High-rise Buildings and Urban Habitat (CTBUH, 2022). Town planning departments of municipalities, regulatory agencies, standards organizations, and communities frequently develop definitions and rules for what counts as a high rise building within their respective jurisdictions. For instance, according to the Milton Town's High-rise Building Guidelines, a high-rise building is one whose height exceeds the neighbouring street's right-of-way or is broader than two streets if it is situated at a junction. High-rise structures in Milton will begin at around 11 storeys due to the right of way lengths, which in Milton are 35 m for arterials and 47 m for regional roads. However, the standards document recognises that a structure with nine storeys would be seen as reasonably high-rise; as a result, the criteria for high-rise buildings should be implemented wherever the structure seems high-rise in proportion to its surroundings (Milton, 2018). High-rise structures in Russia are those that stand at least 75 meters high-rise (Generalov et al., 2018).

The National Building Code of Nigeria (2006) lacks a definition or guidelines for high-rise or high-rise buildings. According to the Lagos State Urban and Regional Planning Development Law, a high-rise structure is one that has more than five storeys (including the ground floor) and/or is high-riseer than 12 meters above the ground (LSURPD, 2019). As far as structural engineering is concerned, a building can be categorized as a high-rise building whenever lateral pressures begin to have a noticeable impact on the behaviour and stability of the building (Islam & Islam, 2013).

3 BUILDING COLLAPSE IN THE WORLD

Building collapse happens to be a phenomenon which spreads round the globe. This implies that it is an occurrence not restricted to just underdeveloped and developing nations but is also found in developed nations (Anosike, 2021). Many individuals have been made homeless due to recurring building collapses, and many have been devastated by the death of loved ones. The frequency and reasons for occurrence, however, vary from one climate to another because the causes of these collapse in advanced nations most times are due to natural forces/disasters such as flood, earthquake, tsunami, etc.

The issue of building collapse is not strange in Nigeria, as it has become a frequent happening. Over the last 20 years, Nigeria has ranked as the country with the most building collapse in Africa (Boateng, 2020). According to a study carried out by (Umo et al., 2018), about 186 buildings were estimated to have collapsed from 1974 to 2017 and over half of these collapses happened in Lagos state. Okunola also noted that about 152 buildings collapsed in Lagos between 2005 and 2020, out of which 76.6% happened to be residential, 13.0% were commercial, and institutional buildings accounted for the remaining 9.4% (Okunola, 2021). Okunola went ahead to carry out a little survey on why residential buildings were dominating the cases of building collapse. He found out that there was increased demand for accommodation due to the high influx of people into the state. Due to this, developers try to play smart by building big structures in areas that can accommodate minimal load, thereby trying to save cost. He also noted that most of these buildings were owned by individuals who try to save cost by engaging quacks, instead of engaging professionals (Okunola, 2021).

Unlike natural forces which happens to be the reason of most building collapse in developed nations, the causes of building collapse in developing nation can be traced to human factors. Several reasons have been touted as the causes of these buildings collapse according to research carried out by several persons, some of which are poor supervision, poor quality or substandard materials, a disregard for standards and regulations, a lack of qualified professionals, overloading, a lack of geotechnical or subsoil investigations, poor construction practices, unlawful approval, incorrect demolition procedures, a lack of maintenance, among many other factors (Ajufoh et al., 2014; Akpabot et al., 2018; Ede, 2010; Adetunji et al., 2018; Odeyemi et al., 2019; Oyegbile et al., 2012; Windapo & Rotimi, 2012).

4 DATA AND METHOD OF ANALYSIS

Historical data of building collapse in Nigeria in the last decade (2012-2022) were considered for this research. The scope of this research was limited to the last decade so as to work with the most recent data available and ensure that this research falls within current trend. Analysis of the data collected were performed with MS Excel statistical tools. The basic parameters considered for the research are the number of floors, the frequency of each group of floors, the casualty verified for each group of floors, monthly record of collapse, status of building prior to collapse, confirmed causes of building collapse and striking differences between collapse of high-rise buildings and others. For this research, high-rise buildings are assumed to be five story and above.

5 RESULTS AND DISCUSSIONS

The total number of cases of building collapse that was considered for this study is 66 cases over the last decade (2012-2022). Figure 1 presents the records of building collapse with respect to the heights of the buildings within the last decade. Three storey buildings are the most collapsed. It can be seen that the incidence of collapse is least for high-rise buildings and large mono-volume building. This can be attributed to the fact that developers or clients who engage in the construction of high-rise buildings are well exposed and well knowledgeable on the need to engage seasoned professionals for any form of construction work. The large mono-volume buildings refer to mega single storey buildings meant for large crowd like mega church buildings.

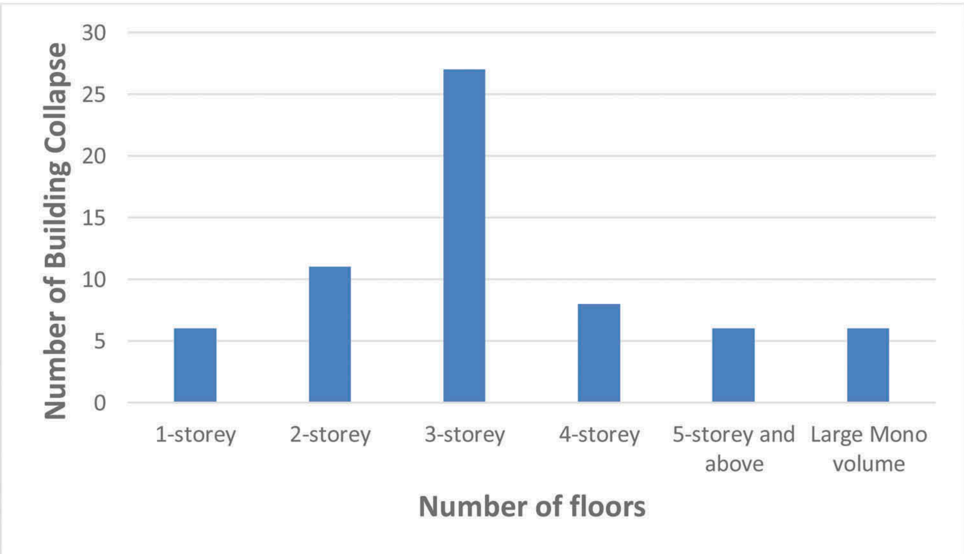

Figure 1. Record of building collapse with respect to the heights of the buildings (2012-2022).

Figure 2 shows the number of casualties associated to each group of floors. It can be seen that the casualties associated with high-rise buildings and large mono volume buildings far exceed those of other group of floors. The large mono-volume buildings refer to mega single storey buildings meant for large crowd. The high rate of casualties linked to high-rise buildings reflects the difficulties involved in realizing such buildings which only highly skilled professionals can handle.

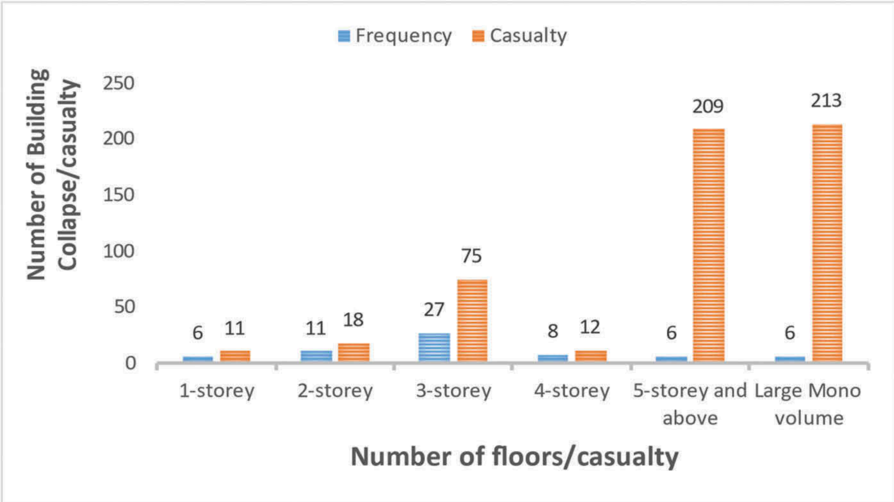

Figure 2. Record of casualties associated to the number of floors.

Figure 3 shows the monthly record of collapse of buildings in Nigeria within the period considered. The raining season is the most dangerous period for the risk of collapse, collaborating results obtained for the previous decade (Ede, 2010). The month of July is the peak month for collapse in Nigeria. From Figure 4, it can be seen that most of the building collapse occur more often for buildings under construction (64% of the cases considered).

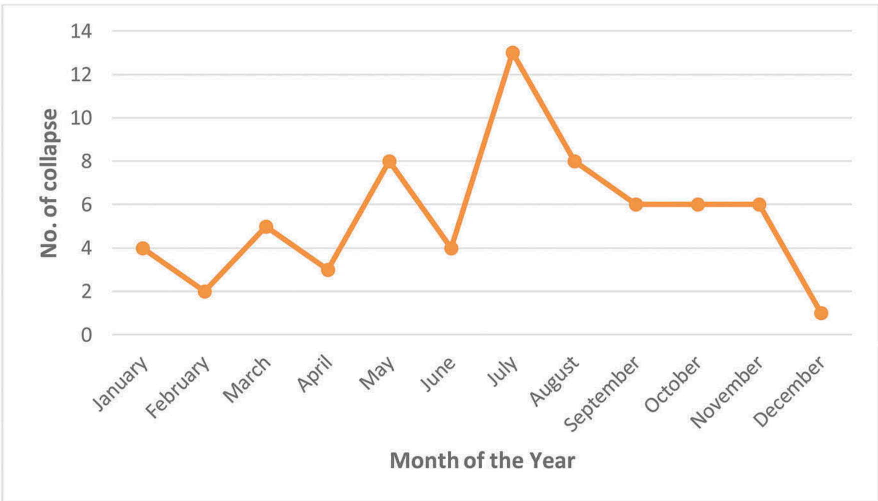

Figure 3. Monthly record of collapse of buildings in Nigeria (2012-2022).

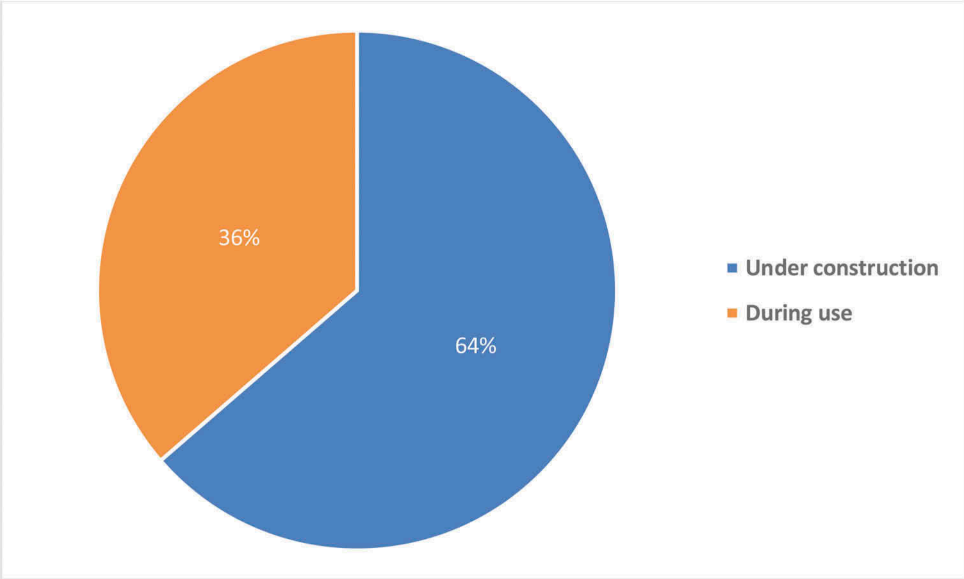

Figure 4. Status of building prior to collapse.

Figure 5 shows the common causes of building collapse in Nigeria within the last decade. It can be seen that most of the causes are difficult to ascertain (29.33%). Other prominent causes verified are substandard materials (20%), structural deficiency from poor construction (18.67%) and illegal conversion/addition of more floors (14.67%). Most of the causes of building collapses can be linked to each other. The various results gotten can be related to each other. From Figure 3, it was shown that the month with the highest collapse rate was July, which happens to coincide with the peak of the rainy season in Nigeria. As a result, it is critical to consider how changing climates will impact these investments over the design life of these structures. This requires proper planning, with an integrated design approach, construction and operation of the building infrastructures, which is very key to sustainability and resilience in building infrastructures (ASCE, 2008; Pal et al., 2022). This is also imperative as climate change is expected to increase the frequency and severity of certain types of extreme weather. It is expected that heat waves will be more severe, storm surges in coastal areas will be amplified, and precipitation will be more intense as a result of climate change. High rise buildings could all be affected by these changes, which could lead to increased delays as well as damage and failure. Hence, the need for an integrated design approach incorporating all relevant professionals required for building sustainable and resilient infrastructures.

In developing sustainable building infrastructures, a working knowledge of the state of the art relating to structural materials and systems coupled with their approximate carbon content is also essential in the proper utilization of locally sourced and accessible materials in building constructions for sustainable, safe, resilient, and economic building constructions (ASCE, 2008). This necessitates the further training of construction professionals to strengthen the sustainable and effective planning, execution and operation building infrastructures. This is essential to avoid future collapses due to flawed construction practices especially with the significant failures that have due to the use of substandard materials as illustrated in Figure 5.

Geotechnical studies should also be done because they provide valuable information that can be used for proper foundation design and other types of construction of civil engineering structures in order to minimize negative effects and prevent problems after construction (Nwankwoala et al., 2014).

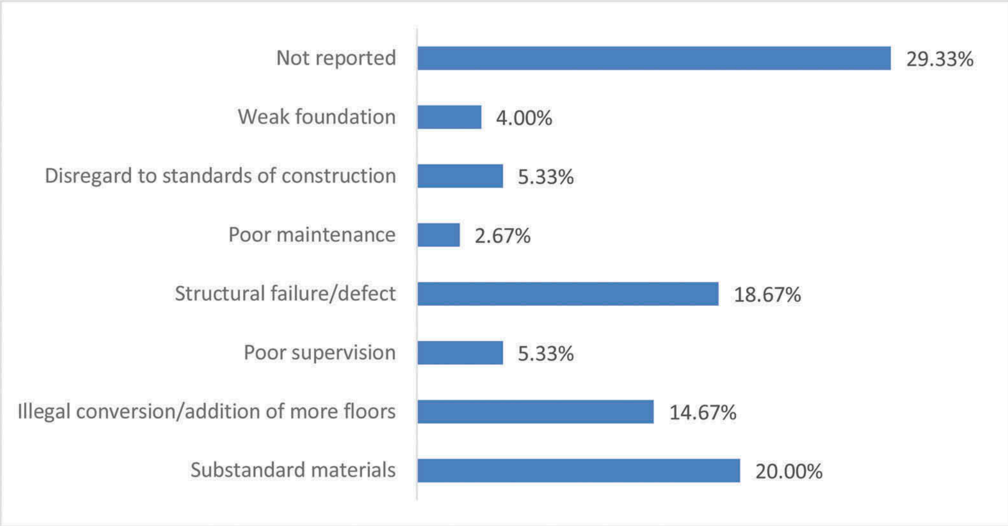

Figure 5. Causes of building collapse in Nigeria (2012-2022).

6 CONCLUSION

From the results obtained from this study as shown in Figure 1, it has been established that there are very few cases of the collapse of high-rise buildings in Nigeria when compared to the collapse of buildings of lower heights. This can be attributed to the engagement of more seasoned professionals in the construction of high-rise buildings. On the other hand, the very high rate of casualties verified for high-rise building collapse is scaring. Adequate safety measures need to be adopted to reduce to the barest minimum the risk collapse of high-rise buildings. Proper project planning and identification of probable risk with the integration of all relevant professionals is crucial in for a sustainable building construction. The development of high-rise structures has been on the rise in several parts of Nigeria, particularly in Lagos State. This is due to urbanization and a need to maximize the land space available. The very few cases of collapse of high-rise buildings shows that Nigeria as a nation can cope with the technicality and advancement that comes with the construction of these high-rise buildings. The frightening scenario of casualties linked to the collapse of high-rise buildings raises the question of how much still needs to be done in Nigeria to fully adopt and incorporate sustainable construction practices into the Nigerian construction industry processes, knowing that the environment in which we operate is changing and the conventional tools with which we use to plan projects are changing too. An understanding of these changes is also crucial to deal with the challenging future. Hence, developing new tools and focus that are required to respond to these changes is also essential.

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Smart infrastructure and cities

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)

An investigation into pre-project planning challenges on public building projects in Zambia

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ABSTRACT: The Auditor general's report in Zambia from 2006 to 2021 indicate that various public projects in the building sector are characterized with project delays, cost overruns and quality issues. While these manifest in the implementation stage, this study sought to investigate pre-project planning practices and challenges. A positivist approach was taken in a cross sectional manner through the use of a self-administered questionnaire to collect data. Purposive sampling method was used to identify consultants involved in pre-project planning of public building projects. Data analysis was done using quantitative content analysis for open ended questions and responses were ranked using means and standard deviations for the closed questions to find the challenges faced during the pre-project planning phase. Findings indicate that some consultants were not aware of the tools applicable, they had insufficient, unavailable funds, planning based on unreliable information, political interference and poor stakeholder as challenges.

1 INTRODUCTION

Every client embarking on a construction project wants to have a successful project more so a public client as they use public funds to sponsor projects. Project success can be measured using various levels namely project efficiency (meeting cost time and quality goals), impact on the customer, business and preparing for the future (Shenhar et al. 2001). Pre-project planning is one of the contributors to project success (Serrador 2012; Kumbhare & Warudkar, 2017) though Anderson (1996) argues that due to unforeseeable activities or outcomes it is difficult to plan accurately. However, there is a consensus in literature that how well pre-project planning is performed affects cost and schedule performance of a project (Kumbhare & Warudkar, 2017 Lester, 2017). It is therefore implied that poor planning negatively affects the aforementioned parameters. In the Zambian construction industry, many public sector projects have quality shortfalls, cost and schedule overruns as evidenced in the auditor general's reports from 2006 to 2020 (Auditor general office, 2020). Furthermore, projects of different sizes and types ranging from roads, bridges and building (Schools, hospitals, clinics and offices) projects exhibit the same characteristics of poor performance regardless of size implying poor planning

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at times. In Ethiopia, Tekle (2020) found that there was a limitation in identifying, quantifying, specifying and planning accurately different project risks, equipment and materials using purposively selected professionals in pre-project planning. Past research in Zambia revealed some form of pre-project planning being undertaken (Kaliba, Muya & Sichombo 2013; Tembo 2018) hence the task was to decipher the challenges experienced during the preplanning stage that result in unsuccessful projects, some of which are evident in the implementation phase of a project. Other studies have brought out the challenges in pre-project planning such as Aghimien, et al. (2018), Edkin et al., (2013) and Hansen, (2018) however the challenges in the Zambian building sector are unknown. Studying challenges that affect the pre-project planning is significant as planning contributes to project success and knowing the challenges supports better planning as these once known can be minimized or eliminated in the Zambian building sector.

The next section discuses literature on pre-project planning; what is constitutes, its importance, and the possible challenges. After which, the methodology used for the study is given, followed by research findings and discussion. Finally, conclusions for the study are given. Further to this recommendations are given for practice and directions for future research are indicated.

1.1 *Pre-project planning*

Mintzberg (1981), defines planning as the process of deciding what to do, when to do and how to do prior to the actual execution. This plan becomes the reference for work during project implementation and therefore collaborative planning increases chances of project acceptability and success (Makalani, 2016). Collaboration can be among internal stakeholders and external stakeholders of the project at hand. Luceno (2018) characterizes a good plan as one that is easily shareable to everyone involved and it is most useful when it is revisited regularly. A plan only starts once a project has been decided upon. The decision to go ahead with a project may be based on market demand, technological advancement, legal requirement, government regulation, or environmental consideration (Rowe, 2015). Regardless of the reason for a project, pre-project planning is vital to ensure a project is successful.

Pre-project planning is the project phase encompassing all the tasks between project initiations to detailed design (Wang & Gibson, 2016). Pre-project planning is a process of developing sufficient strategic information for owners to address risk and decide to commit resources to maximize the chance for a successful project (Kumbhare & Warudkar, 2017) in terms of schedule success, operational success and financial success (Wang & Gibson, 2016). Success is normally indicated traditionally by a project delivered within budget and schedule and having the required quality. Pre-project planning is undertaken by professionals (architects, engineers, quantity surveyors, construction managers, project managers and others) as it is part of their professional training. The client or owner plays a key role in the project preplanning process though may be assisted by consultants if unknowledgeable or if they find it desirable to have consultants plan. The process of pre-project planning signifies a comprehensive framework for detailed project planning. Additionally, Sherif & Price (1999) pointed out that the pre-project planning stage comprises team selection, project charter and project plan as main activities. Consequently, the building sector suffers from poor or incomplete project scope definition, frequently experiencing considerable changes that result in significant cost and schedule overruns (Edward, 2003).

Construction Industry Institute (CII) (1995) indicates four stages in the pre-project planning process. The first stage is the organisation stages under which team selection, draft charter and preparation of pre-project plan are done. It is in the second stage where the selection of alternatives take place such as analysis of technology, evaluation of sites, preparation of conceptual scope &estimates are done and evaluation of alternatives. The third stage consists of: development of project package with activities such as document scope and design, definition of project execution approach, establishment of project control guidelines and compilation of project definition package. Scope definition includes analysis of project risks; documentation of the scope design; definition of project execution plan; establishment of project control guidelines and compilation of the project definition package (Sherif & Price, 1999). The last stage is where the decision is made as to proceed or not with a project. While the aforementioned stages are used; what is common practice is to use a front end planning approach which comprises of a feasibility, concept, detailed scope and design (CII, 2013). These processes are achieved using a number of tools selected as required such as project definition rating index (Bingham, 2010), Scope definition (Sherif & Price, 1999), Team alignment (CII, 1995), alignment thermometer (Sherif & Price 1999), and value engineering programmes (Lester, 2017). The aforementioned stages use techniques and tools of various natures ranging from checklist, to simulations and workflows (Aghimien, et al., 2018; Lester, 2017; Sherif & Price, 1999).

Planning has proven to be crucial in the successful delivery of any project (Lester, 2017). Planning makes it easy to understand how the project team intends to execute the work in a systematic manner, which will facilitate achievement of the project objectives. Furthermore, planning also improves ease of identification of the project risks. It is important to establish the manner in which the activities are to be completed. This will be carried out as the process to indicate whether it will be possible, given the available resources. (Aghimien, et al., 2018).

1.2 *Challenges in pre-project planning*

Aghimien, et al., (2018), Edkin, et al., (2013) and Hansen, (2018) pointout that various challenges may be faced during the pre-project planning phase that may be classified as major and minor challenges as shown in Table 1 leading to holdups and blockages in the pre-project planning process and poor performance in the execution phase.

Table 1. Challenges.

Major Challenges	Minor challenges
• Inability to identify importance of the process, • Unreliable information during early project stages, • Insufficient time to thoroughly carry out the front-end loading process, • Indecisiveness or lack of knowledge by the client, and • Lack of structured project team during inception phases of the project.	• Insufficient budget to carry out the front-end loading process, • Insufficient knowledge on the process by the project team, • The uncertainty of project schedule, • The uncertainty of project budget and, • The uncertainty of project delivery method. • Poor stakeholder management and engagement

Source: Adapted from Aghimien, et al., (2018); Edkin, et al. (2013) & Hansen, (2018).

From the above challenges Makalani (2016) adds political interference. This view is in line with Czarniawska (2012) who argues that planning of projects is always entangled with politics especially on public projects. This is notwithstanding the fact that when projects fail; the technocrats are blamed for political decisions (Makalani, 2016; Czarniawska, 2012). The next section explains the research methodology chosen for the research.

2 RESEARCH METHODOLOGY

Previous literature established that pre-project planning was being practiced by consultants (Kaliba, Muya & Sichombo, 2013; Tembo, 2018) yet failed projects are characteristic of most building projects outcomes in the Zambian construction industry. This study is focused on building projects only as they are in the majority of projects embarked on by the public sector in terms of numbers. The study therefore sought to establish challenges in the pre-project planning phase. A positivist approach was taken using a survey as a strategy to purposively collect information from purposively selected public consultants involved in pre-project planning in a cross-sectional manner. The consultants include Architects, Quantity Surveyors and Engineers (mechanical, electrical, civil). Only consultants in the Architectural, Quantity Surveying and Engineering category involved in planning for public building construction projects were targeted for this research as they play an important role in providing preliminary designs, cost and schedule performance, operating parameters of the project, as well as the overall financial accomplishment of the project during pre-project planning stage. The population sample of all the four categories of planning institutions was drawn from the following ministries: Ministry of Housing and Infrastructure Development, Ministry of Health, Ministry of Education and the Ministry of Local government and rural development. The instrument used to collect data was a questionnaire during August of 2020. Consultants were recruited at the identified ministries upon confirmation of being involved in the planning of public building projects as the sample was purposive in nature. The Ministries plan major projects which are rolled out in the ten provinces across country. The ministries have several consultants however not all are involved in planning. A figure was not given to ascertain how many were involved in planning but on average each planning department had at least eight people involved on building projects in the planning phase. Leedy and Ormrod (2010) propose using 5 to 25 respondents for a purposive sample and this was exceeded as the study had 28 purposive respondents.

The questionnaire used had five sections namely general information (gender, age, and experience), Project delays (number, frequency), Pre-project planning (practices, activities); tools used and project implementation challenges. This was self-administered to the consultants. Qualitative and quantitative data was collected as questionnaire had closed and open-ended questions. For the closed questions most used a five point Likert scale. The analysis was done using quantitative content analysis and descriptive statistics respectively owing to the small sample size and the sample was not randomly selected in nature. Some measures were taken to ensure reliability and validity of the data collected. Data editing was done to ensure missing, invalid or inconsistent entries were captured (Gray, 2009). Data was also checked for outliners and none were found. For reliability, consistency of measurement was achieved through using the same questionnaire (Robson, 2011) and approaching practicing professionals as a source of information.

3 RESULTS AND DISCUSSION

3.1 *Respondent characteristics*

From all the four institutions, the number of respondents who participated in the survey were as follows; ten were Architects, seven were Quantity Surveyors, ten were Civil Engineers and one was a Mechanical Engineer. Of these five were female while twenty-three were male. Twenty of the respondents had spent 3-5 years in the construction industry, five had spent 6-11 years and those with 11-15 years in the construction industry were three. In terms of qualifications one had attained a master's degree, those with bachelor's degree or equivalent accounted for twenty-one of the total number of respondents and those with diplomas were six. From the consultants 25 had worked on over five projects for the past five years, two had worked on about 3-5 projects and only 1 worked on about 1-2 projects for the past five years. From the projects undertaken, on average over 5 projects carried out had experienced project delays and cost overruns as indicated by 18 of the respondents, 3-5 projects experienced projects delays and cost overruns as revealed by six of the respondents and project delays and cost overruns were experienced on 1-2 projects in the past five years as indicated by six of the respondents. The respondents had worked on different types of buildings hospitals, clinics, markets, schools, universities and others. The respondents generally had worked on a good mix of projects and were experienced and qualified in their fields of expertise hence the information sourced could be deemed as reliable.

3.2 *Pre-project planning importance and application*

All the respondents indicated that project planning is an important step that needs to be included in all projects. Only four practice the first stage of pre-project planning which is organizing for pre-project planning while the remaining 24/28 do not practice it. Only 8 out of 28 practice the second stage which is selecting project alternatives while 20/28 do not practice it. Nine practice developing the scope definition of a project which is the third stage while 19 do not practice it. Nothing was revealed on practice in terms of how the decision is made to proceed with a project. It appears that once a project is identified it must be implemented regardless of what the pre-project planning phase may reveal.

It was also of interest to find out if once plans are made they are actually implemented; eight out of the 28 respondents revealed that pre-project planning is always implemented on construction projects, 10 revealed that it is often implemented on construction project. Nine of respondents indicated that pre-project planning is only implemented sometimes while one indicated that it is never implemented at all. The finding show that not all that is planned is implemented during the execution phase of the project though generally pre-project planning is considered as an important activity.

3.3 *Activities done during pre-project planning*

Table 2 shows the various activities done by the consultants as part of their pre-project planning. The focus in the planning revealed material estimates and costs as activities of interest. Looking at alternatives projects, analysis of technology and risk analysis is not widely practiced yet these should actually form part of the go and no-go decision on a project.

Having established the activities done during the pre-project planning stage, It was also important to identify the limitations encountered when carryout the activities done in the pre-projects planning stage. These were revealed in an open-ended question which revealed inadequate finance, lack of specialized tools/equipment such as software for planning, preparation of budgets before project appraisal, political interference, bureaucratic processes and inadequate resource allocation for the preplanning activities. From the responses it is clear that though the pre-project planning stage is seen as important very little thought is put in the preparation process given the emergence of financial inadequacies and also activities conducted.

Table 2. Pre-project planning activities.

Factors	N	Min	Max	Mean	Rank
Material estimates	28	1	4	3.61	1
Preliminary cost estimates are conducted	28	2	4	3.39	2
Clients incorporate other professionals	28	2	4	3.14	3
A team specifically assigned to perform pre-project planning	28	1	4	3.13	4
A written procedure for defining responsibilities and roles of the team	28	2	4	3.07	5
Analyze risks, define project execution, establish guideline and scope definition	28	1	4	2.96	6
Alternatives analysis	28	1	4	2.71	7
Valid N (listwise)	28				

Various practices impact on whether the pre-project planning is going to be successful or be able to account for failure. Table 3 shows the extent to which the various practices and outcomes are experienced. From the table, the awarding of contracts without confirming funds availability, improper designs, inadequate/poor scope definition and lack of coordination are seen to contribute to project failure.

Table 3. Project planning practices and outcomes experienced.

Factors	N	Min	Max	Mean	Rank
Awarding contracts without confirming availability of funds contributes to cash flow problems.	28	1	5	4.43	1
Improper designs at inception have resulted in increased project costs due to variations.	28	1	5	4.29	2
Inadequate scope definition and planning leads to delayed project deliverables.	28	1	5	4.18	3
Uncoordinated plans have delayed project implementation in the past.	28	1	5	4.11	4
Poor scope definition leads to final project costs higher because of the unavoidable changes which interrupt project pace,	28	1	5	4.07	5
Valid N (listwise)	28				

3.4 *Pre-project planning tools*

In the construction industry activities for planning a project are all centered on scope of the project, team members and the needed work activities. Table 4 shows the tools that are used to achieve the aforementioned activities in the Zambian building sector.

Table 4. Pre-project planning tools.

Pre-Project Planning Tools	N	Minimum	Maximum	Mean	Rank
Scope Definition checklist	28	3	5	4.00	1
Work Process Flow diagram	28	1	5	3.64	2
Team Alignment	28	1	5	3.04	3
Value Engineering programs	28	1	5	2.79	4
Project Definition Rating Index (PDRI)	28	1	5	2.61	5
The Alignment Thermometer	28	1	5	2.14	6

During pre-project planning stage, most of the respondents use scope definition checklist and work process flow diagrams. Team alignment, value engineering programs and Project Definition Rating Index (PDRI) are used to some extent while the alignment thermometer is the least used by the respondents during pre-project planning. Therefore, it can be deduced that there is no way of determining whether the team is focusing on the issues and processes that have a substantial effect on team alignment during the pre-project planning phase. Other respondents indicated that they use work flow plans shown in Table 4 under work process flow diagram and network diagrams using Microsoft project. From the results it is clear that some consultants are not aware of certain planning tools as there were several who have never used certain tools indicated by minimum one in Table 4. In Ethiopia Tekle (2020) found PDRI as a common tool yet this is not the case in the Zambian building sector as shown in Table 4.

3.5 *Challenges of pre-project planning on building projects*

Various challenges affect public sector projects. Table 4 shows the various challenges affecting pre-project planning. Over half of the holdup includes, unrealistic information about the site and/project, schedule uncertainty, insufficient time for planning and insufficient budget for the pre-project planning activities. Knowledge of the pre-project planning was indicated as the least challenge therefore it can be concluded that the professionals are aware of what they are supposed to do but are hampered by information, uncertainty, time and budgets. Additionally in incremental order the open ended questions echoed lack of funding, and added political influence, uncoordinated stakeholder engagement, inability to define roles and responsibilities for team members; lack of manpower and inconsistencies in implementing the pre-project planning as additional challenges faced.

Table 5. Challenges of pre-project planning Implementation on building projects.

Factors	N	Min	Max	Mean	Rank
Unreliable information during early project stages	28	1	5	4.32	1
The uncertainty of project schedule, project budget and project delivery method	28	1	5	4.29	2
Insufficient time to thoroughly carry out the front-end loading process	28	2	5	4.14	3
Insufficient budget to carry out the front-end loading process	28	1	5	4.14	4
Inability to identify importance of the pre-project planning process	28	1	5	4.11	5
Lack of structured project team during inception phases of the project	28	1	5	3.93	6
Insufficient knowledge on the process by the project team	28	1	5	3.64	7
Indecisiveness or lack of knowledge by the client	28	1	5	3.61	8

4 DISCUSSION

Pre-project planning is an important stage in the life of a project that enhances project success and reduces project failure if done properly. This section discusses the findings in view of practices, tools and challenges as revealed in the primary data and existing literature.

Public sector consultants view pre-project planning as an important stage in the project management and consequently in project success. The importance of project planning is supported by Lester (2017) who argues that pre-planning contributes to project success. The most utilized tool is the project scope check list while the least utilized tool is the alignment thermometer. It was also clear that a good number of consultants did not know which tools to use. The top three activities of interest are material estimates, cost estimates and identification of other professionals. Tekle (2020) in Ethiopia found d the aforementioned to be sources of poor planning hence it is good practice to focus on these. The least performed activity is the analysis of alternatives. When alternatives are not analyzed it is unclear whether public clients get the best possible projects. It is also unclear what informs the go/ no go decisions on projects as considering alternatives should be a major driver as pointed out by Lester (2017). In the Zambian building sector, specifically in the public sector, it appears that the pre-project planning is for preselected projects which entails that the sector is not making the most use of the stage by reviewing alternatives. Therefore future practice should look at alternatives critically to provide the best projects possible.

Widespread practices resulting in unsuccessful project delivery emanating from pre-project planning in order of effect include; awarding contracts without confirming source of funding, improper designs at inception resulting in cost overruns, inadequate scope definition, poorly coordinated plan, and poor scope definition. Findings reveal that more emphasis in practice should be placed in the project definition stage as this is considered as a cause of changes, cost and schedule overruns in building projects by Edward (2003) if not properly performed. It has been revealed that in the pre-project planning no active risk analysis is done, there is a lack of clarity in control and execution approaches put in place to be implemented in the execution phase. This there calls for active risk analysis and control mechanisms to be planned for.

Unreliable information during early project stages about the site and the project, the uncertainty of project schedule, project budget and project delivery method, insufficient time to thoroughly carry out the front-end loading process, political interference and poor stakeholder engagement are challenges affecting pre-project planning in the Zambian construction industry. Aghimien, et al., (2018), Edkin, et al. (2013) & Hansen, (2018) categorise the challenges as major and minor in Table 1. Of the challenges affecting the Zambian construction industry, there is a combination of both major and minor challenges all with the potential to derail project success in the final analysis. Additionally, Makalani (2016) found political interference as a challenge in pre-project planning which is also identified in the Zambian context. Technocrats should make the decisions that enable projects success in practice. Furthermore, awarding of project without clarifying on funding is also problematic as it does not guarantee project success financially resulting in uncommpleted or abandoned projects undertaken

(Tembo, 2018). Projects should commence only when the source of financing is ascertained to avoid the afforemened. In the final analysis professionals are aware of what they are supposed to do but are hampered by information, uncertainty, unavailability of tools, time and budgets. Having given the discussion on the study the next section concludes the study.

5 CONCLUSION

Pre-project planning is considered to be an important stage in ensuring project success. The project scope check list is the most utilized tool while the least utilized tool is the alignment thermometer with a good number of consultants not knowing what tools to use at this stage. Pre-project planning of project is not holistically conducted as important aspects such site evaluation, value engineering, and risk analysis are not actively done and therefore more attention should be paid to this to avoid future changes, cost and schedule overruns on projects. Analysis of alternatives in the pre-project planning process is not undertaken. This should be considered to ensure public clients get the best projects possible.

The challenges affecting pre-project planning were unknown in the Zambian building sector. This study therefore bridges this gap by identifying the main challenges. The main challenge affecting pre-project planning are unreliable information during the early stages of planning and going ahead to award a contract for a project who's funding is uncertain. It is unclear why this is so. It is recommended that more information about the site and project be sought from inception of the planning phase. Technocrats should also be left to make technical decisions without the interference of the politicians to enhance project success as political interference was identified as a challenge. For future studies case studies could be undertaken to better understand pre-project planning. Lessons can also be drawn from private sector practice of pre-project planning. This study only reported on pre-project planning done building projects, it would be beneficial to have a holistic view of how planning is done in other types of construction projects such as roads, dams, bridges and others.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Assessing the state of Johannesburg water infrastructure and its impact on the residents

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ABSTRACT: The increase in demand for water in urban areas has led to water management becoming an important part of integrated urban infrastructure planning and management. However, challenges such as urbanization, climate change and funding inadequacy continue to threaten water infrastructure provisioning and management. In South Africa, the City of Johannesburg is faced with these challenges. This study assessed the state of Johannesburg water infrastructure and its impact on the residents as not enough study is written about it. Data collected through interviews with Johannesburg Water, questionnaires with residents and peer-reviewed journals were used in the study. Findings revealed that water Infrastructure in the City is in a poor state due to years of underfunding and rapid urbanization. Hence, as a result, many residents experienced loss of income and risks to their health. This study concludes by suggesting solution through coordinated effort of all stakeholders involved together with public private partners.

Keywords: Water, Infrastructure, Management, Urbanization, Accessibility

1 INTRODUCTION

Water "infrastructure management both in developed and developing nations has remained a challenge with over 600 million people still highly reliant on unsafe water sources such as springs and unprotected wells. Water is also central to the sustainable development goals in particular SDG 6 that requires everyone to have access to water and sanitation by 2030 (Maruve, 2019:1). Rapid urbanization in developing countries has created a massive demand for basic infrastructures such as water thus putting cities under enormous pressure to meet these demands (Loucks & Beek, 2017). The City of Johannesburg is among the cities currently faced with an increase in demand for water infrastructures due to challenges such as rapid urbanization, climate change, insufficient fund and spatial dis-configuration.

However, despite the challenges, the City still prides itself as a world class African city with world class infrastructure (BusinessTech, 2013). It has a population estimate of over 5.5million people with a national Gross Domestic Product (GDP) contribution of 14.9%, making it the biggest and most advanced commercial city in Africa and engine room of South Africa's economy (Cooperative governance and traditional affairs, 2021). To ensure the socio-economic development of any area it most have adequate infrastructure capacity, this include its water infrastructure. Given the commercial and strategic importance of Johannesburg City, there is a need to ensure continuous availability and access to water by her residents. In light of the above, this study focused on assessing the state of Johannesburg water infrastructure and its impact on the residents. The study contributed towards the understanding of the true state of Johannesburg water infrastructure and its socio-economic implications since not

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enough has been written about it. To achieve the study objective, primary and secondary data collected through interview, questionnaires and peer-reviewed articles were used to assess the water infrastructure and subsequently determine its socio-economic impact to the residents."

2 LITERATURE REVIEW

2.1 *Introduction*

This literature review defines and provides an overview of urban water infrastructure in the City of Johannesburg, its management and importance, and challenges facing it. The literature review is conducted using secondary data collected through Journals and peer reviewed articles. The review is structured in the following thematic ways: (I) Definition and overview of urban water infrastructure; (II) The importance of urban water infrastructure and management; and Challenges facing urban water infrastructure.

2.2 *Definition and overview of urban water infrastructure*

According to Tumbare (2015), an urban water infrastructure is defined as the "critical component needed in the provision of sustainable water resource management and services." Furthermore, Loucks and van Beek (2017), describes it as consisting of components such as; "water collection and storage facilities at source sites, water transportation routes such as (canals, tunnels, and/or pipelines) from source sites to water treatment facilities; water treatment, storage, and distribution systems; wastewater collection (sewer) systems and treatment; and urban drainage works." From the definitions, urban water infrastructure, is among the bulk infrastructures needed for the sustainable development of cities. As it is required for the delivering of water services and sanitations in a city. In the City of Johannesburg, Johannesburg Water (JW) is the agency responsible for the management and delivering of water services. It has an infrastructure capacity of 128 reservoirs and water towers, 10 network depots, 4 laboratories, 12364km of water pipes, 11710km of waste water networks, water pump stations, 38 sewer pump stations, 11816km of sewer collector network and 6 waste water treatment works. It uses to supply 1.6billion litres of potable water per day including the treatment of 979MI of sewage at its waste water treatment works (Johannesburg Water, 2022).

2.3 *The importance of urban water infrastructure, management and challenges*

As people migrate to cities in search of better economic opportunities and higher standard of living, water design and its management has become an important part of integrated urban infrastructure planning and management. This is to ensure the continuous delivery of water and sanitation services to the urban residents (Loucks & Beek, 2017). According to Calderón and Servén (2010), "an adequate supply of infrastructure services is viewed as the key ingredient for economic development." Throughout history urban water infrastructure has strived to provide health through adequate water supply and sanitation, safety from floods, and well-being for citizens through parks, fountains and healthy waterways and ecosystems (Trommsdorf, 2015). "The benefits associated with the provision of water infrastructure can never be overemphasized as every living-thing depends on water for their survival including economic growth. In the City of Johannesburg, the provision and maintenance of high quality water infrastructure service is necessary to foster and maintain the socio-economic growth of the City.

However, challenges such as Rapid urbanization coupled with climate change in developing countries has created a massive demand for basic infrastructures such as water thus putting cities under enormous pressure to meet these demands (Loucks & Beek, 2017). Every day, around the world, 200,000 people move to the city to settle leading to cities growing at unprecedented rate. This new challenge requires us to plan our water infrastructures differently (Trommsdorf, 2015). In the City of Johannesburg, rapid urbanization is one of the major challenges facing the City. Due to the too much influx of people to the City and the City's inability to plan for them, the

City's infrastructure especially the water infrastructure is put under enormous pressure resulting to damage and interruption to water and sanitation delivery services (Mbanjwa, 2018). An example, is the Alexandra Township located in the region A of the City adjacent to Sandton economic hub. The Township serves as home to many of the Cities urban migrant. However, due to the informal nature of the Township many of the residents are without access to basic amenities such as electricity, water and sanitation services. Thus, as a result, they turn to illegal connections to the City's infrastructure amenities putting pressures on them and sometimes causing damages to the amenities (Mbanjwa, 2018). In 2018, due to the impact of climate change on water resources, the City of Cape Town was on the brink of shutting down. The impact of the climate change left a major economic downturn on the City's economy including her residents (Alexander, 2019). Imagine if such scenario should happen to a city like the City of Johannesburg with a population of 5.5million and national GDP contribution of 14.9%. This means the resultant negative impact on the economy and on her residents will be so massive the country as a whole will struggle to cope. All these including spatial dis-configuration due to legacy of apartheid and underfunding have been identified as the major challenges facing the City's water infrastructure.

3 METHODOLOGY

This section described the research academic methodologies employed in this paper. In the following paragraphs, the appropriateness of the chosen research approach is established, including the description of the empirical data collection and data analysis methods.

3.1 *Research design*

A research design constitutes of the operational plan being utilised to obtain a valid, objective, reliable and accurate findings with regards to the research question/purpose of the research (Kumar, 2011). Therefore, the researcher`s preferred choice of research design was a case study. Case study research design was preferred as it was deemed the most suitable research design for the phenomena been assessed. This is because the study involves the assessment of urban water infrastructure and its subsequent impact on residents of a particular region in this case, the City of Johannesburg which is a major economic and financial hub for the country. The reason for choosing the City is because of its economic importance to the country and the fact that not enough studies talks about the state of its water infrastructure and how it impacts on the socioeconomic lives of the residents.

3.2 *Research approach (mixed method)*

The researcher employed mixed-method approach for the data collection. Qualitative approach was deemed appropriate in that the phenomena (Johannesburg Water Infrastructure) been investigated required deep understanding of its state of affairs and subsequent impact on the residents. In this instance, contextual factors such as meanings of reality could not be measured through quantitative methods. However, the qualitative approach was limited as it could not be used to generate statistical data such as the rating of the Johannesburg water infrastructure and frequency of service interruption among others needed for better understanding and analysis of the phenomena. Both method complimented each other as the qualitative approach described the data while quantitative using numbers quantified it, thus helping to produce quantifiable and reliable data that were generalizable to some larger population of the City.

3.3 *Types of data collected including sample size*

This study made use of both primary and secondary data. The primary data collected includes interview with 2 officials from the management positions of Johannesburg Water, 5 field and maintenance officers, self-administered questionnaire to institutions such as businesses (restaurants, car wash centres) and hospitals, households including community leaders and site visit to reservoir and pump station centres. While the secondary data collected includes peer-reviewed journal articles sourced from Springer-Link, google scholar and municipal website. A total of 50 participants selected from different regions of the City took part in the data collection. 7 officials from Johannesburg Water (JW) were interviewed while the other remaining 43 participants were given questionnaires. 2 of the 7 JW officials were from top level management positions while the remaining 5 were from lower level positions. The reason for such is to have a comprehensive and deep understanding of the phenomena been assessed. The top level officials provided short and long term challenges of the phenomena while the field/lower level officials provided day to day challenges. The remaining 43 participants were selected to represent the varied profiles of people living in the City such as location, gender, employment status among others. The selection method used were a combination of probability and non-probability sampling methods particularly systematic and purposive sampling. The reason for using both sampling techniques is to ensure balance and minimize bias in the selection processes. Example only field managers with 3-5years experience were selected for interview. While every 7th house on right and every 14th house on the left were given questionnaires in any identified area until the number of participant needed in that area is met.

3.4 *Data collection tools*

The following data collection tools were employed in this study; semi-structured interviews, field observation, self-administered questionnaires and documents such as peer-reviewed journal articles. The semi-structured interviews, helped the researcher ask follow up questions and get deeper insight into the state of affairs of the City's water infrastructure. While the self-administered questionnaires were used to collect statistical data to draw conclusion on the level of impact the state of the water infrastructure is having on the residents. Meanwhile, field observations were carried out by the researcher to some of the facilities of the Johannesburg Water such as the Hursthill water reservoir in brixton, Linden reservoir and Helderkruin pump station in roodepoort. The aim was to observe for itself the state of these water infrastructures, as often times they are not well documented. It helped the researcher get closer to the phenomena being investigated while remaining an outside visitor. Lastly, documents; Peer-reviewed journal articles pertaining to the subject matter were collected through Springer-Link, google scholar and municipal official websites to substantiate some of the findings.

3.5 *Data analysis*

Data collected from the "questionnaires was entered in a Microsoft excel worksheets where responses are compared and trends analysed using pivot tables, bar and pie charts, which were features for analysing trends in excel worksheets. The interview conducted were recorded allowing the researcher to listen to it again after the interview and transcribe into a notebook. While data collected through questionnaires were entered into a micro-soft excel worksheets were percentage responses were calculated, profiled and displayed in tables, pic and bar charts. Meanwhile for information collected through journal and articles document analysis was used. This method employs a systematic technique for assessing or evaluating printed and electronic (computer-based and Internet-transmitted) documents. It includes text (words) and photos acquired without the participation of the researcher. In the end the information extracted is organized and categorized into topics significant to the case study."

4 FINDINGS AND DISCUSSIONS

4.1 *Introduction*

This section summarizes and discusses the findings on the City of Johannesburg water infrastructure and its impact on the residents. This section is structured in the following thematic ways: Demographic profile of the participants, Access to reliable water infrastructure, state of the water infrastructure, impacts on the people and challenges facing the water infrastructure.

4.2 *Demographic profile of participants*

The Figures (1&2) below show the characteristics of the participants who took part in data collection in relation to their gender and educational background.

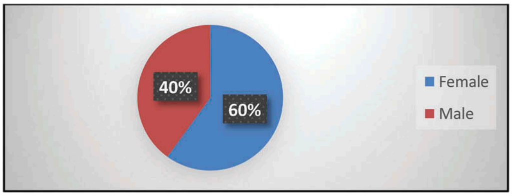

Figure 1. Gender profile of participants.

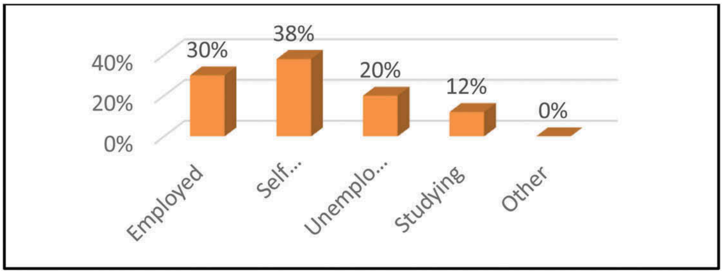

Figure 2. Employment profile of participants.

According to the data collected, as shown in Figure 1, 30 out of the 50 participants representing 60% (n=30) were female, while the remaining 40% (n=20) were male. This shows that the majority of the participants were female. The reason for having more women participants is because more females were found at homes compared to males who were at work during the time of data collection as it was collected during working hours (between 11am and 5pm). Furthermore, in Figure 2, 38% of the total participants are self-employed, 30% are employed, while the remaining 20% are unemployed and 12% studying. This indicates that a combine 68% of the total participants are working or earning a living against 32% who are either unemployed or studying. Having majority of the participants self-employed may indicate that they require much water to use for their various activities, thus requires the City to have effective and guaranteed water supply systems.

4.3 *Access to reliable water infrastructure*

Access to reliable water infrastructure is one the key components to ensuring socio-economic growth and development. Figure 3, below shows the water accessibility of the participants

According to data collected as shown in Figure 3, 90% of the participants have access to tap water connected in their homes. While the remaining 10% fetch their water from a community tap, water tanks or a borehole. Access to clean water that is not too far from where the users live is one of the key components of water sustainability. In this regard, given the participants' responses, the City of Johannesburg has done well in this area considering how difficult it was for most people (blacks) to access social amenities such as water during the apartheid era. Although, it can be argued that many residents especially those in the informal settlement still

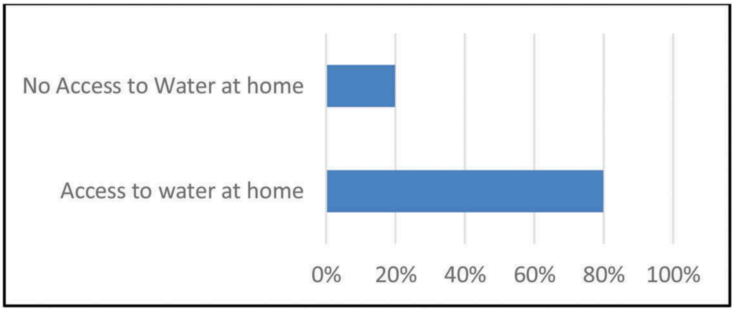

Figure 3. Water accessibility profile of participants.

lack access to reliable water sources. Hence, the City needs to do more to accommodate these communities as they are part of the City and therefore entitled to access to clean water as enshrined in the constitution.

4.4 *State of the City's water infrastructure*

The data obtained shows slow but steady decline of the state of the infrastructure. According to the Johannesburg Water annual report, "R2 billion is required yearly to maintain or replace 12,288 kilometres of water and 11,710 kilometres of sewer networks. However, the budget passed for the year 2021 only allocated R658 million for repairs and maintenance (Haffajee, 2021). Furthermore, data obtained from Haffajee, (2021) shows that the City's water infrastructure is on the verge of collapse, with many of the "City's 87 water reservoirs shut down or pumping at low pressures. In March 2021, over a third of the reservoirs faced supply issues, prompting Johannesburg Water to red-light them and issue a restricted water supply warning." According to Johannesburg Water's annual business plan, the City has an annual "infrastructure renewal backlog of approximately R19.9 billion due to years of under-funding. This has resulted in 25% of the asset base (reservoirs, towers, pipes, etc.) having a remaining useful life of less than 10-years" (Haffajee, 2021). As shown in Figure 4 and 5 below are some the images taken during field observation showing the deteriorating state of the water infrastructure. During the course of the interview with JW top level management officials, inability to attract investment in the water sector was cited as one the reasons this sector is underfunded. However, given the significant importance of the sector one ought to believe that the City together with the JW should be doing everything within the means to ensure that the sector is kept running and adequately maintained. With regards to this evidence showed that not enough is been done to attract the needed investment.

Figure 4. Broken water pipe. source, author's (2022).

Figure 5. Leaking water valve, source, author's (2022).

Figure 4, is a picture of a broken water pipe that is been replaced due to the aging of some of the water infrastructures while Figure 5 is picture of a broken water valve causing water leakage. These images to some degree depicts the deteriorating state of the water infrastructure

4.5 *Impacts on the people*

The responses as expressed by the participants on how the state of water infrastructure from the City has impacted on them are stated in theme 4.6 of this chapter. 90% of the participants which represents 45 people confirmed experiencing water cut while 51% (23 people) of the 90%, agreed to have suffered Socio-economic hardship due to the cut. Among those highly affected includes businesses such as restaurants, car wash centres, gym centres and swimming pool/water recreation centres.

4.6 *Socio-economic impacts of water cut on residents*

4.6.1 *Loss of income*

According to the data collected 23 people representing 51% of the participants that experienced water cut are businesses owners/self-employed. They experienced income loss the most. This is due to their business heavily reliant on water supply from the City therefore not able to operate. Example of such businesses are restaurants and car wash operations. According to a car wash owner interviewed in Soweto, they make huge amount of loss anytime they experience water cut. This affects their livelihood. These goes to show how water cuts in the City affects many residents. Most businesses and institutions in the City needs running water in order to function. Given the economic and financial importance of the City to the country including her residents, water related issues needs to be prioritized in order to avoid a situation similar to day zero in Cape Town City were the City was on the brink of running out of water.

4.6.2 *Economic stagnation*

Some residents highlighted how their communities are always affected as a result of protest arising due to water supply shortages. These protests bring economic activities within the communities to a standstill. And equally, results to destruction of properties. Therefore, income of many residents gets affected. Water is a basic right and it is needed for our everyday life. The lack of water witnessed by communities within the City pushes the city backwards in terms achieving economic growth and development.

4.6.3 *Health risks*

Many residents especially those in the informal settlements and Township lamented how water cuts exposed them to the risk of getting infected with diseases such as covid-19. They said due to insufficient water supply they could not keep up with the hygiene protocols such as washing of hands proposed by the health department during the lockdown. This is quite shameful especially for a City that prides itself as a world class City. The City needs to prioritize service delivery such as water to all her residents as a stepping stone towards achieving her world class status.

4.6.4 *Threat to institutions*
In Helen Joseph hospital, according to a report by Haffajee, (2021) due to persistent water cuts experienced in the hospital many surgeries are constantly postponed. This poses great danger to the health of those patients involved and also contribute to the weakening of the capacity of the institution to function properly.

4.6.5 *Threat to foreign investment*
Many residents expressed concerns on how increased water cuts together with power cuts will be affecting foreign investing in the City. Some believed that the City is no longer the number choice for foreign investors like it was 5-10 years back. Therefore, this deprives the City the employment opportunity that would have been created.

4.7 *Challenges facing the water infrastructure*

Some of the common challenges facing the City's water infrastructure as identified through data collection includes urbanization, climate change, aging infrastructure and underfunding. These challenges are affecting the City's ability to provide sustainable water infrastructural services to her residents. Therefore, jeopardizing the socio-economic growth and development of the City in the long run.

5 CONCLUSION AND RECOMMENDATION

This section provides brief summary on the result of the findings as it relates to the study objectives (I) assessing the state of the City's water infrastructure and (II) identifying its impact on the residents. It highlights the type of data used and their sources and ends by providing recommendations.

In light of the above, this study concludes by stating the following; the state of Johannesburg Water infrastructure in the short and mid-term is in a manageable condition but needs a major overhaul in the long-term. Most of the sub-structures such as water and sewer pipes needs replacement in short and mid-term as they have exceeded their life cycle. There is a need to invest in sustainable power supply to ensure constant supply of power to its pump stations and recycling plants. Challenges such as rapid urbanization and lack of finance has been identified as the major challenges threatening the water infrastructure therefore, the City needs to look for partnership with private sectors to help alleviate this problem. The impact of the poor state of the water infrastructure on the residents is quite significant and jeopardizes the ability of the City to pursue significant social and economic growth and development. Therefore, the City must prioritize the sustainable development of this sector.

To achieve the study objectives, the study made use of both primary and secondary data collected through semi-structured interviews, questionnaires, observation, journals and articles from University of Johannesburg, google scholar and the City's official website

Therefore, this study concludes by suggesting that the City's water infrastructure management requires strategic planning, integration and coordination of several stakeholders responsible for water provision and infrastructure management, and adequate human and financial resources. To achieve this, the paper recommends the following;

1. The City needs to partner with private investors to help raise they needed fund to cover the budget deficit required to fund the infrastructure backlog.

2. The City needs to invest in digital technology to help it timeously detect and respond to any damage to its infrastructure. This will improve its overall infrastructure management.
3. The City needs to find sustainable ways to support its infrastructure such as investing in sustainable power supply source such as solar to help stabilize its operation and improve its service delivery.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Construction management safety training: Students' perception of spatial presence

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ABSTRACT: The construction industry has the highest number of workplace fatalities. The American Council for Construction Education (ACCE) requires construction management instructors to incorporate construction safety training into curricula. Research supports use of virtual reality (VR) in construction management safety training and has compared VR trainings. It noted that human factors, such as spatial presence capabilities, are missing from construction safety training research. To answer this research need, this article reviewed the literature and examined two VR used in trainings, examined through the lens of the theoretical framework of the Model of Spatial Presence (MSP), i.e. user consciously experiencing the sensation of presence based on a cognitive feeling and an unconscious process, measured using the pre-validated Measurements, Effects, Conditions-Spatial Presence Questionnaire (MEC-SPQ). This article shared methodologies for an instructor-developed construction management safety training and for comparing with an existing construction management training, with steps taken prior to the recommended data collection.

Keywords: construction safety, training, virtual reality, spatial presence, quantitative

1 INTRODUCTION

1.1 *Overview*

Construction is the industry with the highest number of workplace fatalities (U.S. Bureau of Labor Statistics, 2020), and research highlights the importance of virtual reality (VR) use in construction management safety training to mitigate these fatalities (Jeelani et al., 2020; Li et al., 2018; Sacks et al., 2013; Zhoa & Lucas, 2015). In addition, the American Council for Construction Education (ACCE) requires programs in construction management to include construction safety learning outcomes training into university curriculums seeking accreditation. This article reviews recent literature on VR use in construction management safety education, compares previous studies of construction management safety trainings, and examines VR use in trainings through the lens of the theoretical framework of the Model of Spatial Presence (MSP). The literature review provided support for the importance of evaluating construction management ladder safety trainings. The results are two-fold: a method used to develop a construction instructor-developed safety training and a method for evaluating the human factor of spatial presence in construction safety trainings. Validity for the developed methods was supported through application of the theoretical framework of the MSP.

Wirth et al. (2003) defined spatial presence as the user consciously experiencing the sensation of presence, based on a cognitive feeling and an unconscious process. Previous studies

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and this review supported the pre-validated Measurements, Effects, Conditions-Spatial Presence Questionnaire (MEC_SPQ) (Vorderer et al., 2004) as a valid measurement of perceived spatial presence when a user has experienced a virtual environment. Other researchers and the authors posit that spatial presence is a critical factor in the validity of construction management safety training (Jeelani et al., 2020; Li et al., 2018; Sacks et al., 2013; Zhoa & Lucas, 2015). Further, the authors recommend applying the Virtual Reality Spatial Presence Index (VRSPI) to define the strength of the perceived spatial presence on a 5-point scale from *very strong* to *very weak* (Guevara, de Laski-Smith, Ashur, 2020). The VRSPI has been utilized in previous studies (Guevara, de Laski-Smith, Ashur, 2022) to evaluate students' perceived spatial presence in virtual environments. In conclusion, future studies should analyse VR use in construction management safety training utilizing the variable of spatial presence.

2 PURPOSE

2.1 *Purpose*

The purposes of this study were: to perform a review of the literature focusing on VR use in construction safety training, to develop a construction safety instructor-developed training, and to develop a method for evaluation of trainings. The objective of this article was to further the research by highlighting the variable of spatial presence as important in the evaluation of construction safety trainings. The results posited a method for application of a spatial presence evaluation in construction safety trainings.

3 LITERATURE REVIEW

3.1 *Previous studies on VR use in construction management safety training*

There have been multiple studies about construction management safety training, however the previous literature seems to focus on adding VR to existing construction safety training to improve the effectiveness of existing training (Jeelani et al., 2020; Sacks et al., 2013; Zhoa & Lucas, 2015). Jeelani et al., (2020) found an improvement in construction site hazard recognition, when adding virtual construction scenes in addition to real construction scenes. Zhoa and Lucas (2015) developed another virtual reality construction electrical safety training that "allows the user to interact with a simulated 3D environment" (p. 66). Sacks et al. (2013) compared in-person safety training to VR safety training, revealing advantages to the VR safety trainings such as attention and concentration. In conclusion, VR is already known as an effective way to supplement in-person construction management safety training. Next, the literature review will highlight previous comparisons and the variable that researchers are requesting to be examined -spatial presence.

3.2 *Previous studies comparing construction management safety trainings*

Other studies have started to examine the variables that are critical for comparing construction management safety trainings (Eiris et al., 2019; Li et al., 2018). The evaluation indicators that Li et al. (2018) propose are critical for further study are: applicability, effectiveness, usability, and level of sense of presence. Li et al. (2018) also provided an extensive review of current construction safety training variables and requested that further research be performed to measure the validity of these variables of construction safety trainings as they are developed in virtual reality. To support this further, both Eris et al. (2019) and Li et al. (2018) posited that *spatial presence* is critical to measure when evaluating VR use in construction management safety trainings. When looking at the user's sense of presence and hazard identification ability, Eiris et al. (2019) reviewed the construction training spatial presence in a 360-degree panorama versus virtual reality. Eiris et al. defined 360-degree panorama as a "technique that creates an omnidirectional view of the surroundings for the viewer" (p. 2) when viewing a virtual environment on a liquid crystal display monitor; virtual reality was defined as viewing 360 degress with a head mounted display (HMD). Notably, students consistently had a higher feeling of presence with the 360-degree panorama condition than with the VR condition. Therefore, the variable of spatial presence seems to be the missing piece in evaluation of construction management safety trainings. Wang et al. (2022), supported this when identifying the gaps in construction research stating that, "Human factors are rather limited" (p. 1591).

3.3 *Theoretical framework Model of Spatial Presence (MSP)*

To support the above literature review and request for evaluation of the variable of spatial presence in construction management safety trainings, this review next looked at a supporting theoretical framework. The Model of Spatial Presence (MSP) involves the user consciously experiencing the sensation of presence based on a cognitive feeling and an unconscious process (Wirth et al., 2003). The variables include attention, self-location, and actions. Spatial presence is based on an unconscious process, even though users consciously experience the sensation of presence. If feeling strong spatial presence: I feel objects surround me, I feel physically present in the environment, and I am able to make a good estimate of the size of the space. The Measurements, Effects, Conditions-Spatial Presence Questionnaire (MEC-SPQ; Vorderer et al., 2004) is based on the MSP (Wirth et al., 2003) and can be used to measure students' perception. The variable of spatial presence is the human factor that Wang et al. (2022) found to be missing in construction research.

3.4 *Measurements, Effects, Conditions-Spatial Presence Questionnaire (MEC-SPQ)*

The MSP defined spatial presence as the user consciously experiencing the sensation of presence based on a cognitive feeling and an unconscious process, measured using the pre-validated Measurements, Effects, Conditions-Spatial Presence Questionnaire (MEC-SPQ). To support a method for collecting data on the variable of spatial presence, the review referred to the MEC-SPQ which has Cronbach alpha scores ranging from 0.86 to 0.91, thus supporting its validity. The data collection instrument has been used in previous studies on spatial presence (Guevara, de Laski-Smith, Ashur, 2022). The three sub-variables in this tool are: Spatial Situation Model (SSM); Spatial Presence: Self Location (SPSL); and Spatial Presence: Possible Action (SPPA). The MEC-SPQ survey tests participants on their spatial awareness and ability to develop and utilize spatial models for application in real-life scenarios through tactics such as self-location and suspension of disbelief (Vorderer et al., 2004). The survey is used widely in the field to test for spatial awareness. Due to its similarity to the topic of this research, it was applied in the "Implications for Future Research" section.

3.5 *Virtual Reality Spatial Presence Index (VRSPI)*

There is another possible method for measuring the variable of spatial presence, the Virtual Reality Spatial Presence Index (VRSPI) (Guevara, de Laski-Smith & Ashur, 2020). The VRSPI is utilized when humans experience virtual environments that have been evaluated for perceived spatial presence. The VRSPI ranks scores of the VR display format on a 5-point scale spanning from *very strong* to *very weak*. The VRSPI supports research including human perceptions of spatial presence. Application of the VRSPI increases the validity of peer-reviewed research on perceived spatial presence. VR spatial presence capabilities could have unknown effects on dependent variables, human physiological effects, such as heart rate, blood pressure, body temperature, and respiration rate. Figure 1 shows how three VR formats could be assessed and result in VRSPI.

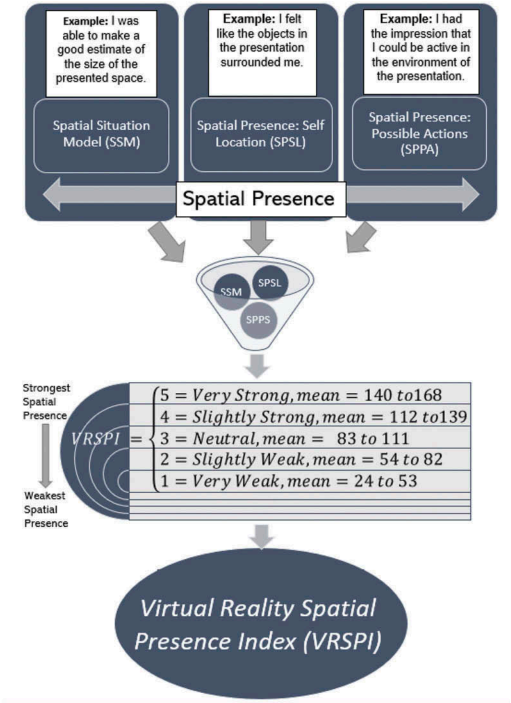

Figure 1. Virtual reality spatial presence index (VRSPI; Guevara, de Laski-Smith, & Ashur, 2020).

4 METHODOLOGY

4.1 *Phase 1: Literature review*

The authors performed a literature review to target VR use in construction management safety education, analyze previous studies comparing construction management safety trainings, and connect the theoretical framework of the MSP. The authors scanned the literature for variables missing from construction research and found human variables as a missing factor. This phase determined the importance of comparing trainings focusing on spatial presence. This phase also questioned whether training developed by construction management safety instructors could reveal stronger perceived spatial presence than training developed by a non-construction focused company.

4.2 *Phase 2: Construction management safety instructor-developed training*

The authors determined the points for developing a construction management safety training, with the critical variable being that the training be developed by the author, a construction management safety training instructor at a university.

4.3 *Phase 3: Pixo, construction management safety training (non-construction management safety instructor-developed)*

Pixo, a developer of VR environments provided the researchers with their construction management ladder safety training. This article's study method utilized Pixo's construction management ladder safety training for the comparison with the instructor developed training.

4.4 *Next, the authors secured use of a construction safety training, Pixo, that was developed by a non-construction focused company. Phase 4: Development of a study to compare trainings*

The authors developed a framework for data collection to compare the participants' perceived spatial presence while experiencing the two construction safety trainings. The authors applied for human subjects' approval to perform the data collection with 50 construction management students as the sample population.

5 RESULTS

5.1 *Instructor-created model and training*

The results of this study shared all steps taken prior to the recommended future data collection. The study produced an instructor-created virtual environment, which started with the construction of a building model. Scenes were rendered and delivered from the modeling application to Yulio. For this model, the default rendering in Sketchup was used with the Yulio plugin. For this study, one scene was utilized with multiple ladder usage scenarios; a ladder was placed strategically where safety concerns may arise when using a ladder. To have consistency across trainings, the instructor-designed Yulio experience focused on scenarios similar to those that the Pixo application addresses. Once the model was created, the VR application, Yulio, was utilized to develop the virtual environment. Yulio is an AEC presentation software the industry uses for client proposals and other visualization portfolios such as student products. Yulio is an effective transition from static slides to a virtual environment in higher education. The critical difference between the Pixo and created trained was that the instructor-designed training allowed for rapid updates to the content in the training. The primary hotspots incli{uded in this model were text annotations when a student selected the hotspot and image annotation displays. Either correct or incorrect (hazards) use on ladders in the instance would appear with the associated Occupational Safety and Health administration (OSHA) rule for that scenario.

5.2 *Framework for data collection*

A framework was developed for data collection, and an application for human subjects' approval was submitted to the authors' university internal review board. The framework for participation and data collection was as follows:

- Participation in this study involves a visit to the virtual reality lab of the university, viewing of two virtual reality devices, and completion of two computer surveys. Participants will be divided into two equal groups named Group 1 and Group2.
- Step 1: While seated for 45 seconds, the participant will view the PIXO Construction Ladder Safety training using a PICO head mounted display (HMD). The research assistant will advise the participant of the time limit.
- Step 2: The participant will complete the MEC_SPQ questionnaire regarding their experience; this will be online and completed confidentially. Following completion of the MEC_SPQ, the participant will raise their hand and the research assistant will guide the participant to the next step.
- Step 3: While seated for 45 seconds, the participant will view the instructor-developed Construction Ladder Safety training in the Oculus Quest VR headset. The research assistant will advise the participant of the time limit.
- Step 4: The participant will complete the MEC_SPQ questionnaire regarding their experience; this will be online and completed confidentially. Following completion of the MEC_SPQ, the participant will raise their hand and the research assistant will guide the participant to the exit.
- Steps 1 through 4 occur in 1 visit which lasts approximately 25 minutes.

- In case of motion sickness, viewing may be terminated, and the participant may be accompanied by the research assistant to the university health center.

5.3 *Framework for data analysis*

A framework was developed for data analysis, based on previous studies evaluating spatial presence with VR use. Mean scores produced from data collection in the MEC_SPQ, applied to the Virtual Reality Spatial Presence Index (VRSPI; Guevara, de Laski-Smith, Ashur, 2020), define the strength of the perceived spatial presence of the two trainings on a 5-point scale from *very strong* to *very weak.*

6 IMPLICATIONS

Many educators in the Architectural, Engineering, and Construction (AEC) industry have a background in modeling tools such as Trimble Sketchup and Autodesk Revit. The modeling tools can create content for virtual environments beyond traditional static digital slides used in teaching and learning. Construction instructor-created trainings, made with the construction process in mind, walk students through project construction tasks such as analyzing construction systems, estimating, scheduling, and safety. If a construction safety instructor develops their own virtual reality training, safety elements can be brought up to add a level of understanding, engagement, and participant spatial presence in the virtual environment. When such a tool is developed, the implication is that human factors should be evaluated to determine the strength of the teaching and learning tool.

7 DISCUSSION AND CONCLUSION

This article highlighted previous researchers' evaluations in the area of virtual reality and construction safety trainings; confirmed previous researchers' claim for the importance of human factors evaluation, such as spatial presence of said construction safety trainings; shared the methodology for this study and resulted in an instructor-developed construction safety training and a framework for data collection and data analysis for a future study. The results of this study shared all steps taken prior to the recommended data collection.

The results posited a method for applying a measurement of spatial presence (from *very strong* to *very weak*) for construction safety trainings. The authors' views on the implication of the results are that this article supports other researchers' view that construction management safety trainings needed to be evaluated and that spatial presence is a critical measurement in supporting the validity of studies that evaluate construction management safety trainings.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)

Implementation of SmartCare Electronic Health Record System project in Zambia using tenets of project management

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ABSTRACT: Studies done on SmartCare Electronic Health Record System are limited when it comes to the success of the project from the developer's view. This study was conducted to determine how effective the system has been run from the development perspective using project management principles. Sample size comprised of the entire population of 82 SmartCare system users from Lusaka district. Closed-ended questionnaires was used to collect quantitative data. According to the study, it was evident by 64 percent of users that the system challenges limited the system efficiency and sustainability. Furthermore, half the users indicated that the performance of SmartCare system was sufficient and met minimum requirements. However, 56 percent indicated that the functionality of the system was below the required standard. The results of this study show that the system performance and functionality are barely meeting software design expectations according to tenets of project management.

Keywords: Health information systems, SmartCare, Performance, Functionality, Project Management

1 INTRODUCTION

Health Information Technology is an application of information technology to healthcare. The application helps improve the quality and effectiveness of healthcare (SelectHub, 2018). Lau et al. (2010) observed that experts consider Health Information Technology key to improving efficiency and quality of health care. The use of Information Technology to improve patient care globally continues to be one of the biggest goals in the health sector (Lau et al., 2010).

If properly implemented, the HIS could allow the use of HIS data not only for patient care and administrative purposes but also for research. HIS is thus an integral part of a functioning health system (WHO, 2008). As stated by the Measure Evaluation website (2019), HIS supports a country's ability to report progress with the aim of meeting global initiatives, such as the Sustainable Development Goals (SDGs), controlling the Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS) epidemic and preventing child and maternal deaths.

To this end, many attempts have been accomplished by the health sector and donors concerning the design, development, and implementation of computerized HIS in developing countries (Kimaro and Nhampossa, 2007). According to the African Health Observatory (2019), significant progress has been made in Zambia in establishing comprehensive routine and periodical HIS for collection, analysis, management, reporting and disseminating vital health data at all the levels of the health sector. A comprehensive set of appropriate HIS has been developed and implemented. Among which the most important one is the SmartCare Electronic Health Record (EHR) System.

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Globally there have been a lot of studies on HISs. Despite the impressive number of these studies available, there has been limited reviews focusing on post-evaluation of elements and characteristics of project success and its process groups of these projects from the system developer's view. Ammenwerth et al., (2016) recommends a rigorous evaluation of HIS technology. Rigorous evaluation studies on different HIS implementation projects in those settings are necessary to understand the critical success and failure factors (Verbeke et al., 2013)

In Zambia, the studies done on SmartCare HIS are limited when it comes to the success of the project from the developer's view using project management principles. To help fill this gap, this study was conducted to determine how effective the system was run from the system development perspective using project management principles in Zambia.

2 LITERATURE REVIEW

2.1 *Definition of project*

PMBOK (2017) defines a project as a temporary endeavor undertaken to create a unique product, service, or result. Projects are undertaken to fulfil objectives (requirements) by producing deliverables. An objective is defined as an outcome toward which work is to be directed, a strategic position to be attained, a purpose to be achieved, a result to be obtained, a product to be produced, or a service to be performed. Software development can be considered as a project. A software development project is a complex undertaking by two or more persons within the boundaries of time, budget, and staff resources that produces new or enhanced computer code that adds significant business value to a new existing business process (Wysocki, 2010).

There are various perspectives of describing project success. Measuring success of an information system is difficult because success does not have a common explicit definition (Van Der Meijden et at., 2003), and is dependent on expectations. The agreed hypothesis to say an information system is successful is when the implemented system is accepted to be used by the end user and the users are satisfied with the system (DeLone et al., 2003).

2.2 *Overview of health information system*

HIS combines different elements of data, or inputs, which are analyzed and processed to produce data outputs (WHO, 2008). However, many HIS which are technically sound for developers and healthcare managers, face resistance from users and end up in failure (Dianna et al., 2013). Several studies have raised concerns about the performance and functionality of HIS(s). Some issues that surround the performance of HIS(s) are system quality, system compatibility (Hamamura et al., 2017), system inefficiency (slow response) (Nguyen et al., 2014), system failures, server crashes, and difficulties in finding HIS that meet user requirement needs (Raglan et al., 2014) which is key in Project Scope Management. Tsai et al., (2020) emphasizes the functionality issues concerning HIS(s). These include both too many complex functions and too few needed functions. Too few functions were reported as barriers to their use. Studies by McAlearney et al., (2010), and Hamamura et al., (2017) agreed that usability such as the design of user interface and navigation were critical features of an HIS. One study showed that the survey respondents (clinicians) were dissatisfied with the usability of HIS at both months 11 and 17 post-HIS implementation (Sockolow et al., (2012).

One of the core components of strengthening health systems globally is the need to improve its development (WHO, 2010). While the benefits of electronic HIS in Southern Africa have been documented in the literature, the implementation of these systems in public health care remains limited (Wright et al.,2017). The determinant factors that affected the information system success in those settings might be different from factors in developed countries. Hence, rigorous evaluation studies on different HIS implementation projects in those settings are necessary to understand the critical success and failure factors (Verbeke et al., 2013).

3 RESEARCH METHOD

To establish the study findings, the project management tenets used were Project Scope Management and Quality Management Knowledge Areas. Descriptive study design was adopted in collecting the relevant evidence to achieve the study objectives. The study population comprised of SmartCare HIS users: Assistant Monitoring and Evaluation (M&E) Officers in Lusaka Zambia.

The entire population of eighty-two (82) Assistant M&E Officers were subjected to the closed-ended questionnaire survey. The research sample size was focused on one region, Lusaka province, and one health system category which is First (1st) Level Hospital. Lusaka province was purposively selected because Lusaka was the first province to roll out and implement the system in the country. Secondary data was collected through literature review.

4 FINDINGS AND DISCUSSIONS

4.1 *Socio-demographic profile of respondents*

The respondent's socio-demographics showed majority of respondents being female with an age group of around 30-34 years, with an academic qualification of first degree with about 2-3 years of work experience. From the 6 first level health systems, majority were from Chelstone. Therefore, the information given by is considered credible.

4.2 *SmartCare system success factors and challenges*

Table 1. Measures of SmartCare system's success factors.

		Variables				
Measurement		Strongly agree	Agree	Disagree	Strongly disagree	Neither disagree nor agree
Satisfied with quality in terms of system dependence	Frequency	1	51	20	1	9
	Percent	1%	62%	25%	1%	11%
SmartCare allows more than one user to access at the same time	Frequency	44	34	2	1	1
	Percent	54%	42%	2%	1%	1%
Satisfied with availability of interfaces that allow access information like lab results	Frequency	13	65	2	1	1
	Percent	15.9%	79.3%	2.4%	1.2%	1.2%
Satisfied with information quality and information system effectiveness	Frequency	2	59	16	0	5
	Percent	2%	72%	20%	0	6%
Satisfied with compatibility of system with other systems	Frequency	2	56	14	2	8
	Percent	2.4%	68.3%	17.1%	2.4%	9.8%

Critical Success Factors (CSF) and challenges are the different internal and external variables or conditions which are critical to the success or failure of a project. Table 1 shows that all five CSF were rated as 'agreed'. The average rate of the ratings 'strongly agree' and 'agree,' is 80 percent. The rate above 80 according to the University of Pretoria (2015), is interpreted as excellent. This indicates that majority of users felt that the system worked according to the required qualities and/or has a high standard and reflects the said success factors.

Dependability is one of the most important facets of a computer system. An investigation in this study revealed that SmartCare system is dependable. Not only did the 63 percent of respondents express confidence in the system, but they accepted the availability, security, and integrity of the system. The respondents also established that an average percent of respondents representing 50 percent felt the system is stable.

A multi-user access system is one that can be accessed by more than one user at a time while running on a single machine. An investigation in this study established that SmartCare system is a multi-user system. The system allows more than one user to access it at the same time. It permits several users to access the central server system database. This is according to 96 percent of study respondents. This means that the system can handle requests from different connected users at the same time.

An interface is a shared boundary across which two or more separate components of a computer system exchange information. This study revealed that the systems interface is available and allows access to information in SmartCare such as Lab information. The computer system allows the user to interact with components of the system. Most respondents, 95.2 percent, alluded that the interface allowed them to access electronic forms that are used to record information stored in the system database.

According to Rai et al (2002), information quality is one of the prerequisites of information system success. it was revealed that SmartCare system is effective and produces good-quality data. 74 percent of respondents were satisfied with the quality of the information and the effectiveness of the health system.

Software compatibility is a characteristic of software systems which can operate satisfactorily together on the same computer, or on different computers linked by a computer network.

It was observed in this study that SmartCare system is compatible with other systems or network environment. The study instead found that the HIS could run on different computer hardware, computer operating systems, applications, network environments or devices. SmartCare system works under different configurations.

Table 2. Measures of SmartCare system's challenges.

Measurement		Variables				
		Strongly agree	Agree	Disagree	Strongly disagree	Neither disagree nor agree
SmartCare has high initial costs such as physical infrastructure like backup power electricity	Frequency	30	48	3	1	0
	Percent	37%	58%	4%	1%	0
Private sectors hesitant to share health information with public hospitals	Frequency	15	30	15	3	19
	Percent	18%	37%	18%	4%	23%
SmartCare-cards lack encryption security feature that can prevent hackers	Frequency	10	49	9	0	14
	Percent	12%	60%	11%	0	17%
SmartCare is linked and integrated with other Health Systems in other facilities	Frequency	3	23	38	9	9
	Percent	4%	28%	46%	11%	11%

Table 2 shows that one out of the four system challenges were rated as 'disagreed'. The average percentage of the ratings 'strongly agree' and 'agree,' of the system challenge measures is 64 percent, which is interpreted as good. This means a sizeable number of respondents agree the system exhibits the challenges. The challenges limited the system efficiency.

High initial and maintenance costs of HIS was investigated. A total of 95 percent of respondents agreed that high initial cost of equipment's such as computer and other physical infrastructure like backup power electricity is among the main challenges of SmartCare system in Zambia. The study therefore established that the high initial costs create a barrier to adoption and implementation of the HIS, especially in rural areas.

A study by Mweebo (2014) revealed that most doctors operating in the private sector in Zambia are hesitant to share patient health information with other hospitals they perceive as competitors. Investigations in this study uncovered that private sector health institutions are hesitant to share health information with public hospitals. Although just over half of all the respondents, 55 percent, supported this. Sharing public health data with the private sector would require more and better engagement to build community understanding about how facilities can collect, share, protect, and use the data.

Encryption is a form of data security in which information is scrambled from plain text into a type of secret code that hackers cannot read, even if they intercept it before it reaches its intended recipients. Studies by Neame (2013) and Mweebo (2014), observed that it is a challenge to ensure privacy and confidentiality through access to health information, using SmartCare system in Zambia, which is restricted and only allowed to those authorized by the patient. The study established that SmartCare-cards, lack the encryption security feature. Most respondents, 72 percent, alluded that SmartCare-cards do not have the encryption feature, thus is prone to be hacked or information on a lost SmartCare-card can be accessed by anyone if inserted into a computer, through a card-reader. In view of this security concern, a secret key that should be entered before access to data on the SmartCare-card is recommended.

System Integration is a process that connects the various IT systems and applications in an enterprise so that they work cohesively in a coordinated and unified manner. Integration is central for HIS. Research by Tsai et al., (2013) highlights the concerns concerning poor interoperability and integration between different health systems and the hindrance of implementation. An investigation in this study, established that SmartCare system is not linked or integrated with other SmartCare sub-systems or health systems in other facilities. Although, a few district, provincial and national databases are linked through SmartCare plus system (web system). This is however at an early stage, and most health facilities are found to have SmartCare legacy system which stores data on a server at the respective health facility.

4.3 *SmartCare system performance (Stability) characteristics*

Table 3. Measures of SmartCare system's performance.

Measurement		Variables				
		Excellent	Good	Fair	Poor	I Don't Know
System user-friendliness in terms of ease access and usage	Frequency	15	51	16	0	0
	Percent	18%	62%	20%	0	0
Time taken to fully load and function	Frequency	5	37	35	4	1
	Percent	6%	45%	43%	5%	1%
Availability of system during heavy demands	Frequency	5	36	34	7	0
	Percent	6%	44%	41%	9%	0
Effectiveness of response time of system interactions	Frequency	7	49	24	2	0
	Percent	9%	60%	29%	2%	0
Accessibility and timely process of requested data from System	Frequency	8	39	32	3	0
	Percent	10%	47%	39%	4%	0
Effectiveness of functions of SmartCare-card reader	Frequency	0	19	28	30	5
	Percent	0	23%	34%	37%	6%
Effectiveness of recovery time from failures such as crush, hang	Frequency	0	14	50	14	4
	Percent	0	17%	61%	17%	5%

Table 3 shows the SmartCare system performance that is moderately good or acceptable. Table 3 therefore, reveals an average percentage of the ratings 'excellent' and 'good' of the performance of SmartCare system at 50 percent indicating that half of the respondents felt that the system works according to the required qualities and performance standards.

User satisfaction is a significant measure of information system success. A study by Mutale (2017) reviewed that health workers perceptions and experiences on SmartCare HIS was good, dependable, and user-friendly. This investigation uncovered that user satisfaction with the system in terms of ease of access and usage is extremely high. Findings showed that the system is an easy, efficient, and more convenient way to store and retrieve patient records.

Software system performance in terms of time taken to fully load and function, or program execution time is measured from program initiation at presentation of some inputs, to termination at the delivery of the last outputs. Aguirre et al, (2019) observes that testing the performance of a system ensures the response times and process interactions are within the system timely and within acceptable limits. An investigation in this study reviewed that time taken for SmartCare system to fully load and function is good. This is according to 51 percent of respondents. The system's response times and process interactions, when loading, are within the system timely and within acceptable limits.

According to Gumede-Moyo et al., (2019), despite the good system architecture, SmartCare system has been reported to have slow system response and software system crashes. Signs of unavailability. The finding seen in this study was that the system experiences software failure, system hangs every now and then and data entry is often interrupted. Investigation found that respondents were uncertain about availability of SmartCare system during heavy demand. Only half of the respondents, 50 percent, responded positively.

System interactions are processes that are accomplished by clicking user interface buttons or links. Clarke et al., (2019) argues that potential benefits of some SmartCare interface modules were frequently unrealized due to infrastructure. An investigation in this study revealed that SmartCare accomplishes various processes by way of clicking the interface buttons or links on time. Most of the respondents representing 69 percent, felt the system was effective.

One of the main objectives of SmartCare system is to provide timely data for patient management while providing automated information flow into the government's existing Health Management Information System trend reporting and analysis for health officials (MoH, 2013). An investigation in this study found that SmartCare data is accessible and processed timely via various reports when requested through interactions. 57 percent of respondents confirmed access and timely process of SmartCare stored data.

A SmartCare-card and Card-reader are computer requirements of SmartCare system. SmartCare-cards are used to store patient data via the card reader from SmartCare software system installed on the computer. An investigation in this study also revealed the functions of SmartCare-card and reader as ineffective. Some of the reported challenges of SmartCare-card and reader are: The software system sometimes does not respond to the reader, the software system hangs or freezes when using the reader, and sometimes the reader does not detect SmartCare-cards.

This study revealed that SmartCare system's recovery time from failures or crashes is ineffective and never produces the desired outcome. This was consistent with the study by Nguyen et al., (2014) which found that the system was inefficient (slow response) and experienced system failures and server crashes. Most respondents in this study revealed that the recovery time is not as expected. The most significant causes of software failure are system overload, resource exhaustion and complex fault recovery routines.

4.4 *SmartCare system functionality (usability) characteristics*

Table 3 shows the SmartCare system functionality (usability) that does not fit user needs. Out of the eight system functionality measures, three were rated as 'yes', four were rated as 'sometimes' and one had an equal percent of 'yes' and 'no'. Most of the respondents did not agree that the system usability met their needs respectively, with an average percentage of the rates indicating 'yes' at 44 percent. Between 40 percent and 49 percent, is interpreted as poor, and depicts a poor number of respondents who felt the system works according to the required qualities and having functional standard.

Lee et al., (2013) observed that SmartCare system is safeguarded using staff login username and password credentials which are not exposed. This study established that users could gain access to SmartCare as per assigned user usernames and passwords created by SmartCare coordinators. The usernames and passwords assist maintain privacy and confidentiality by ensuring that access to health information is restricted and only allowed to those authorized.

Table 3. Measures of SmartCare systems' functionality.

Measurement		Variables: Yes	Sometimes	Rarely	No	I Don't Know
System load with errors or experience system failures	Frequency	5	44	25	8	0
	Percent	6%	54%	30%	10%	0
Users gain access as per assigned user privileges	Frequency	81	1	0	0	0
	Percent	99%	1%	0	0	0
System function offline without online infrastructure such as LAN and Wireless LAN	Frequency	35	2	10	35	0
	Percent	43%	2%	12%	43%	0
SmartCare's major components, e.g., ART, work as required	Frequency	61	9	3	4	5
	Percent	74%	11%	4%	5%	6%
Electronic forms used to record patient information perform as required	Frequency	56	18	2	6	0
	Percent	68.3%	22%	2.4%	7.3%	0
System exhibit errors or experience system failure when storing data	Frequency	21	42	10	8	1
	Percent	26%	51%	12%	10%	1%
SmartCare reports provide accurate, up-to-date, and complete information	Frequency	23	48	6	5	0
	Percent	28%	59%	7%	6%	0
SmartCare-card reader function without errors and system failures	Frequency	9	33	13	21	6
	Percent	11%	40%	16%	26%	7%

Most of the respondents representing 99 percent were able to gain access as per assigned usernames and passwords.

System load is a measure of the amount of computational work that a computer system performs. Investigation in this study revealed that SmartCare system sometimes loads with errors or experience system failure. Slightly over half of respondents, at 54 percent, agreed with this. This was consistent with a report by MoH (2009) which stated that the system contains bugs which cause such errors and failures. Bugs in software can also arise from mistakes and errors made in any computer hardware.

Online or internet infrastructure consists of physical computer hardware, transmission media, and software used to interconnect computers and users on the Internet. This may also include internet servers, internet network equipment, and software. Finding in this study revealed that the distributed mode is used in the absence of internet communication infrastructure. Computers running SmartCare system work independently without any network connection to each other. In this study, an equal percent of respondents agreed and disagreed that SmartCare can function offline without internet infrastructure such as Local Area Network (LAN) and Wireless LAN, which meant that an equal number of respondents, felt that the system could and could not function offline without any online infrastructure.

Guidance on key components that a HIS should possess promotes patient healthcare data. The development of a common set of requirements for the functional capabilities of various HIS software components allow providers to compare the systems that are available and enable vendors to build systems more in line with providers' expectations (Aspdenet al., 2004). Investigation in this study established that SmartCare's major components work as required. This is according to 74 percent of respondents, who agreed to major components working but highlighted that some components such as Record of Birth, Inventory, Under Five, Survey Modules etc. are not functional and/or have not been implemented.

In 2013, the World Health Organization emphasized that HIS contain electronic forms that clinicians or data entry personnel use to record patient information that include counselling and testing, initial history and physical examination, investigations, medication, and long term follow up (WHO, 2013). This study revealed that SmartCare system contains such electronic forms and information such as ART, pharmacy, labs, or antenatal care are recorded into the system.

In Zambia, SmartCare system contains bugs that cause hanging (MoH, 2009). An investigation in this study uncovered that SmartCare systems sometimes exhibit such errors and experience system failure when storing data during data management. This may be because of either the software application or hardware.

Information is only useful if it is up-to-date, accurate and complete. Inaccurate data could mean making a fatal mistake in patient care. Though SmartCare system is viewed as dependable and user-friendly, Clarke et al. (2019), uncovered that database contained incomplete and incongruous data. Several other studies have raised concerns about the performance of HIS(s) suggesting the system produces poor-quality data (Hahn et at., 2013). An investigation in this study revealed that SmartCare system does not always provide accurate, up-to-date, and complete information. This is according to 59 percent of respondents.

The SmartCare-card as stated by the Ministry of Health (2020) is used to store patient data through the Card Reader from SmartCare system installed on the computer. However, findings in this study indicate that the Card Reader sometimes functions with errors and system failures. Most respondents indicated Card Readers as ineffective and experience such issues. Some of the reported challenges of SmartCare-card and reader are: The software system sometimes does not respond to the reader, the software system hangs or freezes when using the reader, and sometimes the reader does not detect SmartCare-cards.

5 CONCLUSIONS AND RECOMMENDATIONS

According to the study, while the implementation was successful, it was evident by 64 percent of users that the system challenges and constraints limited the system efficiency and sustainability. Furthermore, 80 percent revealed the system Critical Success Factors are critical to the project success. Meanwhile, half the users indicated that the performance of SmartCare system was sufficient and met minimum requirements. However, 56 percent indicated that the functionality of the system was below the required standard. The results of the study hence show that the system performance and functionality, are barely meeting software design expectations according to tenets of project management. Thus, depriving productivity standards.

5.1 *Research contributions*

Detailed insight provided by the various similar studies particularly in literature revealed the various system CSFs, challenges, system performance and functionalities. This implies that for effective implementation, HIS such as SmartCare system, should emphasize on the importance of understanding the stated contexts of work.

Another practical contribution of this research is to understand how the SmartCare EHR system development, and other HISs globally, can be developed and build more in line with expectations. This can allow providers to compare with the systems that are available. The due process model established in this study can be used as a practical tool.

5.2 *Recommendations*

Arising from the conclusions documented, the following are the key recommendations focused on implementing and managing SmartCare system project in Zambia: It is therefore recommended that The SmartCare HIS development team should proactively enhance and improve the system performance and functionality to improve productivity standards.

- The Ministry of Health and supporting partners should invest in infrastructure, workflow, and data flow challenges to create new disease modules, for example for Coronavirus (COVID-19) disease or implement other SmartCare modules such as vaccination module.
- The development team should continuously monitor the system qualities and carry out regular maintenance and improvement of SmartCare system.
- The development team to enhance stakeholders' coordination.
- As the pros of SmartCare EHR system outweigh its cons, it is imperative that the Ministry of Health and supporting partners roll-out the system to health centers without the system. The recommendations are likely to enhance long-term outcomes of the SmartCare system project.

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Education, empowerment, gender equity, wellness and development

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

The impact of the 4th industrial revolution on quantity surveying education in South Africa: A qualitative overview on soft skill requirements

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ABSTRACT: The 4th Industrial Revolution (4IR) impacts all economic sectors and forces adaptation to the new reality. The construction sector is not shielded from these changes, thus requiring the quantity surveying industry to adapt its approach to education and professional competencies. The current higher education system in South Africa might not be equipped to address the changes and challenges related to the 4IR. The study aims to identify the specific soft skills required and the level of education needed to equip quantity surveying students to be successful and to be able to adapt to the workforce of the 4IR. Through a qualitative overview, the researcher investigated whether the current education received by quantity surveying students is equipping them with the necessary soft skills. The study's key findings showed that graduates might not be adequately equipped for adaptation to the 4IR workforce.

Keywords: 4th Industrial Revolution (4IR), Graduates, Higher Education, Quantity Surveying, Soft Skills

1 INTRODUCTION

Throughout history, various changes have taken place. The changes that have impacted the world the most are the industrial revolutions from the middle of the 18th century to date. Globally three industrial revolutions have taken place. The 4IR has already begun taking shape and form in the more developed countries worldwide. The impact of revolutions is significant and has a significant impact globally. As they are known today, industries will change and alter the way we see and interact with the world (Dombrowski and Wagner, 2014). Over the last couple of years, advancement in technology has been responsible for the transformation of entire industries, ushering in the 4IR into these industries. The media industry has been changed by services such as Netflix, ShowMax, Spotify, and Joox. Companies like Amazon have changed the face of retailing. These innovative technologies have increased and improved the productivity and sustainability of these companies, but they have also changed the skills required to be successful in the new era (Buehler, Buffet and Castagnino, 2018). With conventional industries changing, new questions are requiring answers: How is transforming technology impacting our lives? How will the evolution of the industry play out? How will job profiles change? What types of skills will be required and demanded to survive in the new industry? These answers are critical to education and industry professionals, as they need to ensure they have an appropriately skilled workforce. With the 4IR aiming to level the playing field between physical, biological, and digital spheres, soft skills

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will become what distinguishes individuals. These skills can be developed and integrated into the education process and create the foundation for complex competencies like creative thinking, problem-solving, teamwork, communication, leadership, interpersonal, and emotional intelligence skills (Balgiu et al., 2017). This study aims to identify if current Quantity Surveying students are receiving appropriate training and teaching to fit the profile for the workforce of 4IR, focusing on soft skill requirements.

2 LITERATURE REVIEW

The [industrial] revolution refers to the change in the industry, with specific reference to economic, social, and technological systems. The first industrial revolution took place in the middle of the 18th century, when the leading economic powers of the day, England, the United States of America, and Germany started changing from an agricultural civilization to an industrial civilization. The invention of the steam engine is characterised as the start of this period as it resulted in standardization of products and procedures, which in turn resulted in more jobs and people moving away from rural areas to urban areas for job opportunities in the factories that came into existence as a result. The second revolution took place in the 19th century and was characterized by the discovery of electricity and the automation of various processes. The iron and steel industries experienced massive growth worldwide. Other significant developments in this time are the development of the car and assembly lines. The third revolution took place in the middle of the 20th century, and many believe the discovery of the microchip in 1971 was the catalyst for the start of this revolution. Technology started developing at an increased pace, changing the workplace forever. With the introduction of the personal computer, productivity increased. Communication was revolutionized with the development of the internet in this period, resulting in the professional force needing to adapt to the changing environment (Dombrowski and Wagner, 2014). The fourth revolution is currently taking place. One of the main reasons it is not just seen as a prolongation of the third revolution is that it is evolving exponentially rather than linearly. The current revolution results in entire industries being disrupted and the transformation of entire governance, management, and production structures. Technological breakthroughs like self-driving cars, 3D printing, nanotechnology, biotechnology, material sciences, energy storage, and quantum computing are providing people with more knowledge, connection to one another, unprecedented processing powers that result in unlimited opportunities, and humankind is only limited by their imagination (Schwab, 2016). According to Balgiu, Cotet and Zaleschi (2017), the 4IR embodies the total transformation of industrial production by combining digital technologies and the internet with conventional industries. The paradigm of the 4IR, when looking at it from the discovery of steam, electricity, and digitization, is that the 4IR has no limits, as seen in the previous three revolutions. The 4IR is going to level the playing field between the physical sphere, biological sphere, and digital sphere. It is aiming to integrate artificial intelligence, cyber-physical systems, cloud computing, robotics, and additive manufacturing. Advancements in nanotechnology, biotechnology, artificial intelligence, and robotics are all resulting in radical remodeling of the labour market as it is known today, creating a change in skills required to address these challenges.

During the second revolution in the 19^{th}-century Quantity Surveying started in England, where people known as surveyors would usually be used to measure completed building work for master tradesmen, and the final account can be submitted to the client. Clients started becoming unhappy that they only received the cost of the project after the completion of the work; they then started asking for tenders before the work on the project began. Building owners later came to the realization, that having a full-time surveyor in their employment that would look after their interests would be beneficial to them in the long run, these surveyors became known as Quantity Surveyors (Maritz & Siglé, 2010).

Quantity Surveying in South Africa started as a result of the discovery of diamonds and gold between 1870 and 1886, when mining started playing a more critical role in a country that was primarily agriculture driven. The mining activities in Kimberly and Witswatersrand attracted architects to the republic who had limited knowledge of tendering and contracting.

Initially, the architects produced their quantities, which were simple and not detailed. In time the architects and building owners realized exact quantities where required, and in 1896, quantity surveyors landed in South Africa (Maritz & Siglé, 2010). The quantity surveyor has become an intricate part of the construction industry in South Africa and has become a specialist in construction economics and provides expert advice regarding the size, standard, and cost of construction projects. The quantity surveyor is also responsible for the preparation of budgets, working with other professionals in the design process, overviewing the tender process and contractual obligations of the parties involved, and preparing the Bill of Quantities (BoQ) and all other documents necessary for the tender process and cost control during the project, this is to ensure that the project stays within the intended projected cost for the project (Maritz & Siglé, 2010).

According to Nnadi, Oyeyipo and Tunnji-Olayeni (2019) the quantity surveyor needs to adapt to the 4IR, and will need to adapt to climate change, digitalization, and economic recession. According to Abdullah, Muhammed, and Nasir (2019) the modern workplace is placing a greater emphasis on soft skills. Soft skills have become a crucial quality required by businesses as a result of the shift to a customer-centered approach. Modern businesses required employees who have soft skills and knowledge that will be beneficial to the organisational culture of the company. According to the WEF (2016) the 4IR is creating a new environment, and these changes often result in a change in the skills required in the industries. With the demand for skills evolving at an increasing pace, the skills required to do various individual jobs within a family of jobs will become more important. The majority of skills required by most occupations by the year 2030 will be made of skills not seen as essential skills currently. Soft skills like emotional intelligence, persuasion, and teaching will be more important than the technical skills required by the majority of occupations. To close the talent gap and acquire the skills required in the industry, the skills required for the 4IR must be identified, current workers need to be educated, and there is a need to attract new talent to the industry. According to Gray (2016), the following 10 skills will be required in the 4IR: complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgment, and decision making, service orientation, negotiation, and cognitive flexibility. Creativity will be one of the most sought-after skills, with all the advances in technologies an employee will have to be creative to take full advantage of them. These changes will require leaders in business, educators, and government to start re-skilling and up-skilling individuals so that they can take full benefit of the 4IR (Gray, 2016).

The effects of the 4IR are starting to be seen in all aspects of life and to fully realise the benefits and potential of the 4IR, a more inventive, inclusive method for talent development needs to be developed. The 4IR will require learning and unlearning skills to create and find new paths forward (Geyer, 2019). The technological changes will require skills to fall outside the existing curriculum and teaching approach. Creative thinking, collaboration, and emotional intelligence will form part of the primary skills needed by future employers (Fleming, 2019). The 4IR is going to change the way we approach education as well as alter what is believed to be necessary skills for students to be successful. Education in the 4IR is going to place a high value on adaptability and self-directed learning and thinking. Developing technologies is going to result in additional requirements for education to ensure that new technologies are implemented thoughtfully and with informed decision-making. These requirements will be a combination of critical thinking, ethical thinking, and intercultural awareness (Penprase, 2018).

According to Penprase (2018), one framework that is suggested for career and technical education will aid quantity surveying graduates who enter the profession in the development and emphasis on soft skills. Higher education has a crucial role to play in shaping the societal transitions necessary for society to adjust to the 4IR. Due to the changes, the 4th Industrial Revolution brings to the Quantity Surveying industry; how will tertiary institutions respond in terms of Quantity Surveying education? The 4th Industrial Revolution is going to demand new soft skills from professionals, and it will be the tertiary institution's responsibility to develop future Quantity Surveyors with the necessary soft skills (WEF, 2018a). According to the WEF (2018a), the first step is that professionals and industry associates must determine the skills that will be necessary for the current revolution to help them accurately predict what skills will be required and how many workers possess those skills and how many will possess these skills. Current industry professionals should also provide feedback to tertiary institutions on how the current curriculum meets the needs of the industry. According to Penprase (2018), higher education has an important role to fill in shaping the transition for the society to adapt and adjust to the 4IR. Higher education as it is today was developed to meet the demands of the previous industrial revolutions, focusing on the needs of mass production and electricity. These systems are not suited for the revolution currently being faced. The challenges faced by students today are no longer bound to the region; the challenges faced worldwide are almost identical such as, population growth, inequality, literacy, climate change, and much more. What students major in will not determine their career, but their deep understanding of the content is what will shape their future.

Higher education, in this case, quantity surveying education, is responsible for the implementation and testing of new technologies and education techniques that will shape the future of the profession. For quantity surveying education to produce graduates with the required skills and knowledge, it is imperative that they ask how the 4IR revolution has impacted higher education (Mezied, 2016). According to the WEF (2018a) 45% of new workers and 42% of employers think the current education received by students is preparing them for entering the construction industry. This highlights the current gap between the existing curriculum being taught and the new skills required by the construction industry. This gap will only continue to grow as the industry becomes more digitized. The skills required in the changing construction industry should be determined; this should then be compared to the current training provided. Along with increased technological skills, students should be taught soft skills. This will allow them to become lifelong learners and start preparing for a job that does not exist yet.

3 RESEARCH METHODOLOGY

The qualitative methods used to collect data were semi-structured interviews with quantity surveying academics/lecturers and focus group discussions with quantity surveying students at a South African University offering quantity surveying education. This is a small sample and the study can be seen as a pilot study. Purposive and convenient sampling was used for the semi-structured interviews as well as the focus groups. Purposive in the sense that it must be lecturers/academics (interviews) and students (focus groups) in the Quantity Surveying discipline specific to investigate the problem at hand and convenient in the sense of the location and time limitation of data collection. Five lecturers were asked to participate in the study and to be interviewed. For the focus groups 2nd years, 3rd years and honours year quantity surveying students were asked to volunteer to participate in the discussions. Five students per year group participated, thus a total of 15 students participated in the focus group discussions. The interviews and focus group discussions were conducted online and not face to face due to Covid-19 pandemic restrictions. The discussions were recorded, transcribed, and thematically grouped and presented. The ethical considerations for the data collection were to ensure that the rights and privacy of the participants were protected. This included but was not limited to voluntary participation, no remuneration, and the anonymity of the participants. The responses from the participants are only accessible to the researcher and the study leader of the researcher. Ethical clearance was obtained for the execution of this study.

4 RESEARCH RESULTS AND DISCUSSION

4.1 Results of interviews with lecturers/academics

The semi-structured interviews were conducted with five lecturers at a South African university offering quantity surveying education, with the intended purpose of the interviews to determine and understand academics' opinions on the current education the students at this university are receiving and the success or failure thereof in preparing the students for the quantity surveying industry and a workforce of the 4IR. The interview consisted of nine questions and was conducted telephonically with each of the lecturers on a date and time that suited them. Due to the Covid-19 pandemic restrictions at that time, it was best to conduct the interviews telephonically and not face to face. At the beginning of the interview, they were reminded that participation was voluntary, and they could decide whether they would continue to participate in the interview or not. The entire process was concluded within forty minutes and was recorded with permission from the participant. The nine questions of the interview focused on the 4IR, soft skills education, and the preparedness of students who graduate from university to enter the quantity surveying industry. Results are collated and presented as a summary of all respondents below.

Q1: Do you know what the 4IR is?
The respondents all had a good understanding of what the 4IR is, and how it is currently in process. 4 out 5 of the lecturers mentioned and highlighted the technological advancements of the 4IR, and how manual operations will be replaced with mechanization in the construction industry.

Q2: Can you explain what soft skills are?
All the respondents demonstrated a good understanding of what soft skills are, describing them as skills that are inherent to an individual, and the individual's ability to work with other people. These skills are not technical skills required to perform specific activities within a profession, but skills required to work and communicate successfully with other people.

Q3: What soft skill(s) do you think students will require to be successful in the 4IR and the changing quantity surveying industry?
The respondents identified various soft skills that quantity surveying students who enter the profession will require to be successful. The primary skill identified by the respondents is emotional intelligence, with the respondents believing that emotional intelligence encompasses a variety of other soft skills like conciliation that will be required to be successful in the quantity surveying industry. The other skills identified by the respondents are complex problem solving and communication. The last skill identified by the respondents is adaptability to technology; this will allow the students to quickly learn new technologies with the aid of knowledge gained from previous technologies.

Q4: Do you think the education/training the students are currently receiving is equipping them with the necessary soft skills to be successful?
Most of the respondents are of the opinion that the current education provided to the students is preparing them to some extent. The respondents are of the opinion that the soft skills being taught are only being taught to a basic level, and the development and implementation of these skills is the responsibility of the individual student to some extent.

Q5: What soft skills do you think the education needs to focus more on?
Communication, active listening, emotional intelligence, critical thinking, and complex problem solving, were identified by the respondents as important soft skills. The majority of respondents stated that more practical experience should be included when soft skills are being taught to ensure students have knowledge of what is expected of them in the workforce.

Q6: Are you of the opinion that the students graduating from this university are prepared for the workforce of the 4IR?
The respondents were divided on whether the students graduating from this institution are prepared for the workforce of the 4IR. Two of the respondents answered no, they do not believe the students are prepared for the workforce of the 4IR, two other respondents answered they believe it depends on the individual student if they are prepared for the workforce, and one respondent answered yes, the students graduating from this institution is prepared for the 4IR workforce.

Q7: What skills do you think are more important, hard, or soft skills? Or are they both equally important?
The respondents answered in the following way, three of the five respondents answered that both hard – and – soft skills are equally important in developing a well-rounded quantity surveyor, 2 out of 5 of the respondents answered that they believe soft skills are more important, they are of the opinion that soft skills are what quantity surveyors use to work with other people. The hard skills required in the industry can be executed by another person, or someone can be appointed to complete the hard skills, but soft skill development is very important.

Q8: Are you of the opinion that it would benefit the students if the soft skills being taught were highlighted with the assessment information?
All the respondents answered that it would benefit the students if the soft skills being taught in the assessment is highlighted with the assessment information. The general opinion is that if the soft skills are highlighted with the assessment information, the students will be more inclined and attentive to focus on soft skill development and apply the effort needed to master the specific soft skill.

Q9: What can the faculty do to prepare students better for the 4IR?
The respondents are divided between including more practical experience in the curriculum to prepare students for what is expected from them in the industry, including more training for technical skills, and including more soft skill modules in the curriculum to create students with a more balanced skill set before they enter the workforce.

4.2 Results of focus group discussions

The focus groups were used to include students currently studying at a South African university. The focus groups were conducted with 2nd year, 3rd year and 4th year (honours) students via an online platform. The different groups consisted of 5 students per group. Focus groups were used to determine the knowledge and experience of the different student groups for the duration of their academic careers. The focus groups were asked questions about the 4IR, soft skills, and soft skill education. The participants were informed at the beginning of the focus group that the process was voluntary and that nobody was forced to participate in the process, and to ensure that the process was conducted ethically, the study leader supervised the sessions. The focus groups were conducted between 24 July and 10 August 2020 and scheduled to ensure that all the participants could participate at an available time. Results from all groups are collated and presented as a summary of all respondents below.

Q1: Do you know what the 4th Industrial Revolution is?
The purpose of the question was to determine if the students in the group understand what the 4IR is, and what the impact is on them and the quantity surveying industry as a whole. From the responses of the various groups, it is clear that the students have a clear understanding of what the 4IR is. According to Penprase (2018), the 4IR can be defined as the fusion of technologies and knowledge. The transformation of technologies and knowledge is occurring since humans have created computers with the capacity to store large amounts of data, which in turn resulted in machine learning.

Q2: Can you explain what soft skills are?
The purpose of the question was to determine whether the groups understand what soft skills are. The groups all understood soft skills like interpersonal skills that an individual uses to work with other people. According to the literature, soft skills can be described as interpersonal qualities, more commonly known as people skills (Robles, 2012: 453).

Q3: What soft skills do you think students will require in the 4IR and changing quantity surveying industry?
All three groups identified problem-solving as an essential soft skill to be successful in the world of work.

Q4: Do you think the education you are currently receiving is equipping you with the necessary soft skills to be successful?
All three (3) groups are of the opinion that their current education is preparing them with some of the skills required for the changing quantity surveying industry, and that the education either needs to focus on more crucial skills or include practical experience in the curriculum to better prepare students for the quantity surveying industry of the 4IR. The problem statement of the research states that the current higher education in South Africa is not equipped to address the changes required by the 4IR.

Q5: What soft skills do you think your education needs to focus more on?
All three groups identified communication as a soft skill their education can focus more on. The 4th years believe that other soft skills can be learned through proper communication training like emotional intelligence, negotiation, and working with others. The 2nd year students identified cognitive flexibility as a soft skill that can receive more attention because they are of the opinion that it will aid students to adapt to the rapidly changing environment of the 4IR. According to the literature, there are 10 skills identified that will be required by all professionals in the 4IR, emotional intelligence is sixth on the list, negotiation is ninth, and cognitive flexibility is tenth (Gray, 2016).

Q6: Do you feel the students graduating from this university are prepared for the workforce of the 4IR? Explain why.
The purpose of the question was to determine if the students believe their education is preparing them for the workforce of the 4IR. All three (3) groups are of the opinion that the students graduating from this university are not prepared for the workforce of the 4IR. According to Fleming (2019), one of the challenges facing education the world over is that the resulting technological change will require skills to fall outside the existing curriculum and teaching approach. Creative thinking, collaboration, and emotional intelligence will form part of the primary skills required by future employers.

Q7: What skills do you think are more important, hard or soft skills? Or are both equally important and explain why?
The purpose of the question was to determine what skills the students believe will be more relevant in the 4IR quantity surveying industry. All three (3) groups were of the opinion that both hard and soft skills are equally important because a quantity surveyor needs to use a combination of these skills to be successful in the industry. According to the literature, the majority of the skills required by most occupations by the year 2030 will be made of skills that are not seen as essential skills currently. Soft skills like emotional intelligence, persuasion, and teaching will be of higher importance than technical skills required in the majority of occupations (WEF, 2016)

Q8: Are you of the opinion that it would benefit students if the soft skill being taught was highlighted with the assessment information?
The purpose of this question was to determine if new approaches to teaching and learning would be acceptable to the students, especially when soft skills are being taught. All three groups are of the opinion that it would benefit students if the soft skills being taught were highlighted with the assessment information, with the primary reason being that it would aid in focusing the student's attention on the required skill that needs to be developed. According to literature, the 4IR is going to change the way we approach education as well as alter what is believed to be necessary skills for students to be successful. Education in the 4IR is going to place a high value on adaptability and self-directed learning and thinking (Penprase, 2018).

Q9: What do you think higher education can focus on to better prepare you for the 4IR?
Two (2) of the groups stated that they believe experience in the 4IR workforce will better prepare students, and one group believes the incorporation of more industry technology and software into the curriculum will better prepare students for the workforce of the 4IR quantity surveying industry. According to the literature, new frameworks needed to be developed

within Career and Technical Education that will help graduates to respond to the increased rate of change and the increased volatility and complexity of employment in the 4IR. These new frameworks will need to move the emphasis away from the routine task that has started to plague the industry, and growth habits to stimulate the mind and develop creativity within all new graduates, no matter the level they are employed (Penprase, 2018).

Data collected from the interviews and focus group discussions indicates that both groups of respondents are well acquainted with the term 4IR and both groups indicated a clear understanding of what soft skills are. Both lecturers and students are in agreement that problem-solving is an important soft skill to develop for adaptation into the workforce for 4IR, in addition to problem-solving as an important soft skill, lecturers also indicated that emotional intelligence, communication, and adaptability skills are also of importance to be successful in the 4IR. Both lecturers and students are hesitant about the acquisition of these important skills in higher education, and it is recommended that more attention should be directed to the development of communication skills especially. Active listing, emotional intelligence, critical thinking, and problem-solving are some of the soft skills that education can focus more on from the lecturer's perspective. In response to the question, of whether students graduating from this institution are prepared for the workforce of 4IR, both groups of respondents (interviews and focus groups) were hesitant and not convinced about the adequate preparation of students and it is recommended that more practical experience be included into the curriculum as well as a stronger focus on the development of soft skills and the inclusion of industry technology and software. The majority of the respondents believe the faculty can improve their training by including work experience in the 4IR workforce to prepare them for situations they will face in the industry.

5 CONCLUSION AND RECOMMENDATIONS

To achieve the purpose of the study, interviews with lecturers, and focus groups with students were conducted. The questions tested the knowledge of the participants regarding the 4IR and soft skills, whether quantity surveying students are prepared with the necessary soft skills for the 4IR, and what tertiary education institutions can do to better prepare quantity surveying graduates for the workforce of the 4IR. The questions for the interview, and focus group were comprised of the participants' knowledge level regarding the 4IR and soft skills, their opinion if quantity surveying graduates are prepared with the necessary soft skills, and what can be done differently in preparing quantity surveying graduates with the necessary soft skills. In the literature review, it was discovered that the 4IR is going to alter the construction industry method of operation including the quantity surveying industry. Soft skills are going to play a bigger role in the industry of the 4IR due to the technical improvements leveling the playing field between hard – and – soft skills. The literature review also revealed that education is also going to have to adapt to the 4IR, changing the approach to include the development of new skills to allow students to adapt to and challenge the 4IR. The research study aimed to investigate if quantity surveying education in South Africa is equipped to prepare quantity surveying students with the necessary soft skills to be successful. The research study showed that all the respondents knew what soft skills are and that they knew what the 4IR is and they all identified similar soft skills future quantity surveying education needs to focus on to better prepare quantity surveying for the workforce of the 4IR. It has emerged that lecturers and students are of the opinion that quantity surveying graduates are not prepared with the necessary soft skills and they all identified additional exposure in the current workforce and practical experience as possible solutions.

As it was revealed that lectures (interviews), and students (focus groups) do not believe that quantity surveying students is prepared with the necessary soft skills for the 4IR, the researcher made the following recommendations:

- New strategies need to be developed to include soft skill education into the curriculum of quantity surveying graduates. This will ensure a new generation of quantity surveyors that can better contribute to the needs and objectives of their companies.
- To better prepare quantity surveying graduates for the 4IR, practical exposure to the current quantity surveying industry is required. This will provide graduates with real-world experiences that they will face and aid in the development of the necessary soft skills required to navigate and be successful in the workforce of the 4IR.

Due to the time constraints, size of the participant group, the responses of participants, and the inclusion of only one tertiary institution the researcher narrowed to investigate convenient participants. The researcher, therefore, suggests the following for further research:

- Investigate soft skill education across a wider variety of tertiary institutions, to determine the preparedness of quantity surveying graduates across South Africa.
- Investigate employers' preparedness to employ quantity surveying graduates based on their acquired soft skills.
- As an extension of curriculum development, investigate how soft skills are currently being taught and the level of development achieved by students.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Challenges faced by professionally registered construction women in South Africa's construction industry

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ABSTRACT: Women in the construction field are still dominated by men, although the world and the construction industry is trying to evolve. Previous research studies have identified a number of challenges experienced by women in the construction industry, namely: discrimination, career support lacking, health and safety problems, and struggling in life and work balance. Previous studies have concentrated more on construction women without regarding if they are qualified in the construction field or not. The research objective was to find the challenges pertaining professionally registered construction women with more than five years of construction experience working in South Africa. A quantitative methodology was utilised wherein a questionnaire was distributed, and 111 construction professional women participated. Key findings: lack of fair income, working long hours, unable to balance life and work, and women still regarded as a stay-at-home partner.

Keywords: Challenges, Construction Women, Professionally Registered, South African Construction Industry

1 INTRODUCTION

Gender inequality is still discussed in the construction industry. In South Africa, gender inequality stems from years of apartheid when women were not allowed to work, move out of the area they lived or go search for employment if they had no required documents (SA History Online, 2019). In post-apartheid governance women are still marginalised in the construction industry, which is still male-dominated. In the continent of Africa, the female construction entrepreneurs experience socio-cultural challenge that is mostly patriarchal (Aneke *et al.*, 2017). Additional challenges include lack of compensation, working environment that is not good, and work that demands more work time which makes it difficult for women to balance work and family (Fouad *et al.*, 2017). The focus on women who work in male- dominated occupations remain important in light of the negative personal and social consequences that women face (Raghuram, 2008). These challenges have contributed to women leaving the construction profession.

Previous studies have mainly focused entirely on construction women in general and not those that are qualified in the field and/or registered with a professional body. Some of these studies are: *Barriers to women in the UK construction* (Worrall *et al.*, 2010), *Women's reasons for leaving the Engineering Field* (Fouad *et al.*, 2017), *Discrimination against women in the construction industry in South-Africa* (Jahn., 2009), *Women in construction: hindrances that shorten the professional working life of female site engineers on construction sites in South Africa* (Sangweni, 2015) and *Investigating the challenges that women employees face in the*

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construction industry in Mpumalanga and Limpopo provinces in South Africa (Malaku, 2021). The gap established is that no study has focussed on the challenges experienced by professionally registered women who have worked for five years and above in South Africa construction industry. In order to seal this gap the objective of the study is to establish the challenges experienced by construction professionally registered women, working in the construction field in South Africa for more than five years.

The challenges endured by construction women, found in the past literature can be identified in these themes: industry discrimination, career support; health, safety and well-being, and balancing work and life in this study.

Industry discrimination: The construction industry is deemed as the world's largest industry employer. In India, more women are found in the construction process, and viewed as secondary or temporary workers with less opportunities for training, guarantees of wages and work benefits (Patel and Pitroda, 2016). The work environment and negative attitudes towards women has exacerbated under-representation of women in the industry. Senior men managers who are older in the industry were found to be patriarchal. They did not like being questioned and rarely want to be given instructions by women (English and Hay, 2015).

When giving tasks and positions in construction workplaces, men tend to get first preference in management and on-site work (Navarro-Astor *et al.*, 2017). Women who work as administrators and managers in smaller construction firms feel isolated. They tend to have low self-esteem and have poor access to career developments (Alessandrini and Winter, 2014). They added that women executives and administrators in Tasmania, Australia have experienced gender issues though working in family- owned or construction businesses. Further, some women did not receive income, but got compensation fund or building business superannuation. Unfair income for women in male-dominated professions is a major challenge (Gaines, 2017). Low income can be experienced by women who have children and are married in comparison to those that are single and do not have children (Bilbo *et al.*, 2014).

Career support: Women working in male-dominated sectors do not receive much support which makes them not be motivated or innovative at work (Gaines, 2017). However, women can create careers that are prosperous within the construction industry and have a positive impact (Haupt and Madikizela, 2010). Women need to be encouraged to participate in construction by being given support as they take career choices that are not traditional (Patel and Pitroda, 2016). Inadequate awareness and expecting performance that is perfect in women, tend to be factors that make women leave careers that are male dominated. In order to persevere, some women tend to seek support and force to be recognized by their male colleagues by copying their behaviour (Gaines, 2017).

Rosa *et al.*, (2017) emphasised that mentors that are seniors in the construction industry tend to assist young professionals in handling issues that are career and psychologically related. Martin and Root (2010), stated that women who own companies in construction lack training, experience and still face gender discrimination. According to Jonas (2015) construction women mentioned the need for mentoring and coaching. It can therefore, be suggested that mentorship and training for women in construction is a fundamental problem, as it could have a negative impact on their career advancement.

Health, safety and well-being: The construction industry is a hazardous workplace for women and men. The environment should be conducive for workers to be psychologically and physically safe (Yildizel *et al.*, 2016). Alewi (2015) study revealed that some women in the construction industry complained about excessive work performed in project sites by using their physical bodies.

Mental health is challenge among construction employees at all levels. This can be caused by late payments by clients to business owners (Gerrard, 2019). Mental health has an influence on how a person thinks, feels and acts about themselves and other people. This could also be influenced by the way they handle situations (good or bad) in their life every day (Department of Health, n.d). Mental health can be caused by stress, depression, lots of anger, anxiety, not sleeping well and having suicidal thoughts. Late payments in the industry impacts the relationships of employees and employers. Some employees and business owners can attempt to commit suicide due to late payments (Gerrard, 2019). Some of the reasons that causes late payments by clients stems from them having lack of financial management, disputes between client and contractor, not processing payment certificates on time and refusing to pay contractors which is deemed unfair (Ansah, 2011). This is detrimental to the finances of contractors or the construction companies (Ansah, 2011), which can then affect an individual's health.

Fumes and dust pollution during construction can affect the workers' health. Furthermore, dust, heat and cold weather can change the temperature of the body and further impact on workers physically and psychologically leading to accidents (Yildizel *et al.*, 2016). Too much heat can on a worker can be detrimental to once health leading to stroke and death. Extreme heat is a catalyst of workers fatigue (Alewi, 2015).

For women who work on construction sites, the sanitary facilities can be a health hazard as they are unhygienic and water for drinking is unclean. More women tend not to use the toilets or drink the water, thus, resulting in heat stress and other health-related issues that can impact their bodies (New York Committee for Occupational Safety and Health, 2014). Women in construction industry have different H&S needs based on their creation. This can make them prone to high dangers on site that could lead to injuries or death (Zungu, 2012).

Lack of the required personal protective equipment (PPE) and workers tasked to work fast contributes to the hazard of workers in construction sites (Leung, Liang and Olomolaiye, 2016). Protective equipment can also cause physical stress which is a job stressor (Leung, Liang and Olomolaiye, 2016). It has been deduced that the design of PPEs does not cater for women. This is risky because it results in injuries. Some women in construction indicated that ill-fitting PPEs' are uncomfortable, thus, they decide not to wear them (New York Committee for Occupational Safety and Health, 2014).

Balancing work and life: Family responsibilities are are constrains in the early phase of career development for women (Adogbo *et al.*, 2015). The construction industry is structurally and culturally male, couple with long working hours, inflexibility and discrimination (English and Hay, 2015). Balancing work and life for career women means having to maintain relationships with family (children, partner or husband, if married) and work performance at the same time. However, a position for a construction project manager requires lengthy hours of work and also working during weekends. This type of position can have negative impact on a professional woman who is married (Bilbo *et al.*, 2014). In Tasmania, Australia women who work in the same construction business (family business) with their husbands still face issues of balancing work or business and family demands, as all the family demands have to be attended to by women (Alesaandrini and Winter, 2014).

The balancing of working hours and being committed to family matters are challenges for women (Adogbo *et al.*, (2015). In addition, managing being pregnant and working on site is a barrier for women. Furthermore in Nigeria, some women have to first ask their husbands if they can work (Adogbo *et al.*, 2015). Women are generally believed to be homemakers and to take care of children, some women find it difficult to balance work and life when they have a career (Rosa *et al.*, 2017). Similarly for women, being a mother and a wife comes first before their careers, thus, they go for temporary work in consideration of their husband's jobs (Gaines, 2017).

2 RESEARCH METHODOLOGY

A quantitative mono-method was used, which is in-line with positivism philosophy. Hence, the study is based on the past existing theory of challenges experienced by construction industry women in the engineering and built environment worldwide, which is male-dominated. The use of inductive approach was not considered as this type of approach requires a field of study with scarce literature generated (Saunders *et al.*, 2016). In using the deductive approach in this study it enabled the researcher to estimate the duration of data collection and analysis.

The construction professional women participants that took part in the questionnaire survey were 111, and having more than five years of working experience in the construction industry. Further, they were professionally registered with the Engineering Council of South Africa (ECSA), South African Council for the Project and Construction Management Professionals (SACPCMP) and the South African Council for Quantity

Surveying Profession (SACQSP) councils regulated by the Council for the Built Environment (n.d) in South Africa. Registered as a: Professional Engineer (Pr. Eng), Professional Construction Manager (Pr. CM), Professional Construction Project Manager (Pr. CPM), and/or Professional Quantity Surveyor (Pr. QS) as they have more than five years of construction work experience.

An electronic questionnaire survey was distributed through LinkedIn and the SACPCMP council website. Unfortunately the SACPCMP was the only council that could assist the researcher with data collection, the other professional councils were not forthcoming. The data was analysed using Stata version 17 software. The results of the fore-mentioned variables were presented. That is, industry discrimination, career support, health, safety and well-being, and balancing work and life challenges. The descriptive statistics were used and ranked using mean value and to some extent the standard deviation was considered. The mean value results have been discussed appropriately by utilising Renault *et al*., (2018) scale ranges, where 1 = Strongly disagree (≥ 1.00 and ≤ 1.80), 2 = Disagree (≥ 1.81 and ≤ 2.60), 3 = Neutral (≥ 2.61 and ≤ 3.40), 4 = Agree (≥ 3.41 and ≤ 4.20), and 5 = Strongly agree (≥ 4.21 and ≤ 5.00).

3 DISCUSSION OF THE RESULTS

The results of the challenges endured by construction professional women in the construction industry in South Africa are presented in Table 1, and discussed thoroughly in each main challenge theme (industry discrimination, career support, health, safety and well-being, and balancing work and life). Each challenge has coded items that have been ranked (*Rank*) based on their mean value (*Mean*) and standard deviation (*Std Dev*). The table also shows the number of participants (*N*) that answered each item.

The result presented in Table 1 *industry discrimination (ID)*, established that the professional women in the industry agreed and were also neutral pertaining to the variables. Further, the overall mean value was of the construct was neutral with a mean of 3.27. The neutral response suggest that these professional women are indecisive of these challenges. The unfair income variable was ranked first with a mean value of 3.54. From the results it can be inferred that the professional construction women believe that they are unfairly paid in the industry, probably compared to their male counterparts. Lack of compensation and the pay that is unequal has been found to be a reason that made engineer women to leave the engineering field (Fouad *et al*., 2017). The second ranked challenge defining industry discrimination was established to be a challenge i.e. senior male mangers do not want instructions from women with a mean value of 3.44. This can be associated with men perceiving women as not capable of handling the duties of the construction field. In a study by Malaku, (2021), the participants indicated that there is discrimination in the construction industry, and that women are deemed not able to perform the job which also requires giving instruction to construction men.

In addition, ID-2 i.e. senior male managers do not want to be questioned by women was ranked third with a mean value of 3.39 suggesting that the professional construction women were neutral regarding this measure. This indicated that they neither agreed nor disagreed that this is a challenge. Therefore, ID-4 i.e. negative attitudes towards women in construction was ranked fourth with a mean of 3.35. This neutral position suggested that the respondents neither agreed nor disagreed with this challenge.

Construction women can feel alone as sometimes they can find themselves being the only female working on-site, which can also cause stress, and the attention they get is not similar to those of males on-site (New York Committee for Occupational Safety and Health, 2014). However, the findings in this study found that, the variable feeling isolated was ranked fifth with a mean value of 3.20, indicating a neutral stance. This result indicated that respondents are impartial regarding feeling isolated in the industry. There is perhaps some improvement in how women are perceived in the working environment as a permanent or temporary worker in the construction industry in South Africa. Variable ID-1 i.e. women still seen as temporary workers was ranked sixth with a mean value of 2.67. The result established that the respondents were unbiased regarding this challenge.

Career support (CS) construct had a mean value of 3.01 as presented in Table 1, indicating that the respondents were neutral. This construct was defined by five variables. CS-4 i.e. poor access to career development was ranked first with a mean of 3.10, indicating a neutral stance by the respondents. This indicated that the respondents neither agreed nor disagreed with this challenge defining career support.

Mentorship has been found by researchers to be one of challenges that women encounter in the construction industry. Mentoring can also be used as a way to break the glass-ceiling in the construction industry where it is male-dominated (Moodley, 2012). Furthermore, construction experience is of importance in the construction industry, and women feel neglected due to not having more of it. Work experience increases an individual's knowledge, skills and increasing experience can assist with being productive at work (Ardianto, 2020). However, from the results, variable CS-5 i.e. neglected because of the lack of construction experience was ranked third and CS-3 i.e. lack of mentoring at work was ranked second. CS-3 mean = 3.06, std. dev. = 1.12, whilst CS-5 mean = 3.06, std. Dev. = 1.15. These measures of career support were rated as neutral and hence not in-line with the aforementioned literature.

While copying male behaviour could be a strategic way for construction women to get support in the construction industry, the results have shown that CS-2 i.e. imitating male behaviour to seek support was ranked fourth with a mean of 2.96 indicating that the respondents were unbiased. Lack of support at a workplace cannot be motivating for an employee. Finally, the result for CS-1 i.e. lack of support by employers was ranked fifth and rated neutral with a mean of 2.80.

Health, safety and well-being (HSW) construct was defined using five variables. Overall this construct attained a mean value of 2.61 suggesting that the respondents neither agreed nor disagreed that it was a challenge. However, the measures defining HSW were established either to be neutral or they disagreed they were challenges. In construction projects, there are those sanitary facilities that need to cater to only women working on-site. The sanitary facilities are supposed to be kept clean, if they are not clean they expose women and other construction workers to diseases and can impact their well- being (Thurman *et al.*, 1989; Health and Safety Executive, 2010). It can be suggested from the result that HSW-3 lack of hygienic sanitary facilities for women was ranked first with a mean of 3.14, indicating the respondents took a neutral stance. They neither agreed nor disagreed with this challenge defining, HSW.

It has been revealed that personal protective equipment (PPE) sizes are mostly designed for males in the construction industry as it is male-dominated. This makes it difficult for women to get PPE that fits them. Variable HSW-5 i.e. oversized PPE was ranked second with a mean value of 2.68, deducing that the respondents were neutral. Hence, it can be inferred that PPE are neither a challenge or not for construction professional women.

It is stated that some women do not drink the water in construction sites (New York Committee for Occupational Safety and Health, 2014). Unclean water can cause illness that can affect workers on-site and affect the project timeline. The current result has shown that HSW-4 i.e. unclean water for drinking in construction projects was ranked third with a mean score of 2.52, indicating that the respondents disagreed that it is a challenge. From this result it can be suggested that construction projects have potable water.

HSW-2 i.e. late payments causing mental health issues was ranked fourth with a mean of 2.44. The result established that the respondents disagreed that this is a challenge in relation to HSW of construction professional women. Hence late payment does not cause health issues.

New York Committee for Occupational Safety and Health (2014), revealed that most women who die in the construction industry are killed by cars while working as flaggers on road construction sites. Furthermore, construction women work in construction offices tend to experience brutality which can result to death. Agyekum *et al.*, (2021) stated harm on the body can be caused by bending and lifting objects, and falling. To establish if this is a challenge variable HSW-1 i.e. experience physical harm on the body due to work was rated. The findings established the respondents disagreed that this is a challenge in relation to HSW of construction professional women. This was ranked fifth with a mean of 2.28.

Balancing work and life (BWL) construct was defined by four variables. Results in Table 1 show that the overall mean value for BWL was neutral. However, the measures defining BWL the professional women indicated that they agree and were also neutral. In line with this findings the construction industry has no good work-life balance due to the working durations, the nature of male-domination in the sector and the travelling distance from home to the office or project sites (Holden and Sunindijo, 2018). In Rosa *et al*., (2017) the women participants stated that it was difficult for them to balance their career goals and life which had an impact on the success of their careers. In validating the literature BWL-2 i.e. difficulty balancing work and family responsibilities was ranked first with a mean of 3.63. The result suggest that construction professional women agreed that BWL-2 was a challenge.

Further, long working hours are detrimental to the life of any working person. The average working hours differ from country to country, in South Africa it 40 or 45 hours per week (Erasmus and du Toit, n.d) and this can affect the health of a person. Psychological stress, work stress and cardiovascular diseases (Wong *et al*., 2019) are found to be one of the effects of working for more than the specified working hours. This can result in less sleep which can also cause coronary heart disease (Cappuccio and Miller, 2017). Therefore, BWL-1 i.e. long working hours experienced was ranked second and with a mean value of 3.59 which was agree with a mean of 3.59 . Therefore, long working hours was a challenge to enable construction professional women with more than five years working experience to balance work and life (family). This finding corroborates with the study of Rosa *et al*., (2017) and Worrall *et al*., (2010). In Fouad *et al*., (2017) the engineering women stated that the work demanded long working hours, which made them to leave their engineering occupations.

Unfortunately, women were regarded to be housewives, which was a stereotype (Adogbo *et al*., 2015). They were not allowed to work, but to be take care of the household and children, whereas men had household responsibilities that are different and could make time for their careers (Rosa *et al*., 2017). To validate this statements, variable BWL-3 i.e. women being perceived as a homemaker or housewife was ranked third with a mean value of 3.45 suggesting an agreement. It can therefore be inferred that women are perceived as a homemaker or housewife. This is a challenge to enable construction professional women with more than five years working experience to balance work and life (family).

As the construction industry is male-dominated, Adogbo *et al*., (2015) stated that women in Nigeria's construction industry would require their husbands' approval to work in construction as some of the husbands would not allow their wives to converse with other men. Some decision-making processes of a working woman can be approved or disapproved by a partner they have in their life. Therefore, variabale BWL-4 i.e. asking for work permission from the partner was ranked fourth and was rated as neutral with a mean of 2.69. The result indicated that the respondents neither agreed nor disagreed with this challenge to enable them to balance work and life (family).

Table 1. Challenges endured by construction professional women.

Code	Challenges Endured	N	Min	Max	Mean	Std Dev	Rank
Industry discrimination							
ID-6	Unfair income	111	1	5	3.54	1.32	1
ID-3	Senior male managers do not want instructions from women	110	1	5	3.44	1.18	2
ID-2	Senior male managers do not want to be questioned by women	111	1	5	3.39	1.29	3
ID-4	Negative attitudes towards women in construction	111	1	5	3.35	1.20	4
ID-5	Feeling isolated	111	1	5	3.20	1.09	5
ID-1	Women still seen as temporary workers	111	1	5	2.67	1.15	6
ID TOTAL MEAN		110	1	5	3.27	0.98	2

(*Continued*)

Table 1. (*Continued*)

Code	Challenges Endured	N	Min	Max	Mean	Std Dev	Rank
Career support							
CS-4	Poor access to career development	110	1	5	3.10	1.13	1
CS-3	Lack of mentoring at work	111	1	5	3.06	1.12	2
CS-5	Neglected because of the lack of construction experience	111	1	5	3.06	1.15	3
CS-2	Imitating male behaviour to seek support	111	1	5	2.96	1.09	4
CS-1	Lack of support by employers	111	1	5	2.80	1.13	5
CS TOTAL MEAN		110	1	5	3.01	0.86	3
Health, safety and well-being							
HSW-3	Lack of hygienic sanitary facilities for women	111	1	5	3.14	1.29	1
HSW-5	Oversized personal protective equipment (PPE)	111	1	5	2.68	1.28	2
HSW-4	Unclean water for drinking in construction projects	111	1	5	2.52	1.13	3
HSW-2	Late payments causing mental health issues	111	1	5	2.44	1.25	4
HSW-1	Experience physical harm on the body due to work	111	1	5	2.28	1.15	5
HSW TOTAL MEAN		111	1	5	2.61	0.90	4
Balancing work and life							
BWL-2	Difficulty balancing work and family responsibilities	111	1	5	3.63	1.06	1
BWL-1	Long working hours experienced	111	1	5	3.59	1.17	2
BWL-3	Women being perceived as a homemaker or housewife	111	1	5	3.45	1.14	3
BWL-4	Asking for work permission from the partner	111	1	5	2.69	1.19	4
BWL TOTAL MEAN		111	1	5	3.34	0.80	1

4 CONCLUSION

The objective of conducting the research study has been achieved, by establishing the main challenges faced by professionally registered construction women in South Africa's construction industry. Thus, the following can be concluded:

Industry discrimination: Construction professional women are unfairly paid in the construction industry. The patriarchy practices by the men in the construction industry is still an issue, as construction indicated by construction professional women. This is detrimental and perceived as undermining the ability of construction professional women.

Career support: It is interesting to note that construction professional women did not experience career support challenges.

Health, safety and well-being: The study revealed that the construction professional women do not experience harm while working in construction projects. In addition, late payments from the client, contractor or employer does not cause any mental health issues for them. It was deduced that construction sites do have clean water for consumption.

Balancing work and life: Construction professional women are required to work for more than the normal occupation working hours in South Africa. The long working hours contributes to an imbalance of work and taking care of their family. In this study, construction professional women are still seen as individuals that need to take care of the home and cater to their partner and/or children.

5 RECOMMENDATIONS

The recommendation from this study is that private and public sector construction industry need to tackle these challenges. There are some changes that have been initiated over the years in the constructions industry. However, organisations should ensure complete change is realised, as this would also be advantageous for the next generation of women that wants to embark in the engineering and built environment career. Public and private entities should allow working hours that are flexible for construction women, in order for them to have a balanced work and life. This will improve their health.

They need to voice out their challenges to their employees and other stakeholders, to contribute to change in the construction culture and working environment. Construction women should be remunerated as their male counterparts based on their experience, skills and qualification. In addition, the construction male professionals should be supportive of construction women without discriminating them.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Identifying the benefits of built environment professionals with competencies for sustainable construction projects in South Africa

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ABSTRACT: Construction activities cause a significant harm to the environment. This harm requires built environment professionals (BEPs) to carry out construction activities in a sustainable way. While numerous studies have identified the benefits of sustainable construction, a limited number of previous studies have identified the benefits of BEPs with competencies for sustainable construction projects (SCPs). The purpose of this study, therefore, was to discover the benefits of having skilled BEPs for SCPs in South Africa. To achieve the purpose of the study a constructivism philosophy was adopted. Twenty-one respondents were purposively sampled and interviewed. The findings were: sustainable solution; public health and safety; client satisfaction; efficient use of resources; and good reputation. It can be inferred that the construction industry will benefit greatly from the BEPs with competencies for SCPs. Therefore, it is recommended that the government make it a requirement for professionals working on SCPs to have the essential competencies.

Keywords: Benefits, competencies, built environment professionals, environment, sustainable construction

1 INTRODUCTION

In the advent of civilisation, people have required large numbers of structures in order to survive. However, during the construction, operation and maintenance of these facilities, as well as their demolition, they inflict a great deal of environmental damage, and this has a direct impact on the society and the economy (Agyekum-Mensah, Knight and Coffey, 2012; Xia *et al.,* 2016; Aghimien, Aigbavboa and Thwala, 2019). Construction activities have the greatest impact on sustainability of the environment compared to any other industry (Willar *et al.,* 2020). Sustainable construction (SC) ensures that all construction activities are carried out in a sustainable manner, from the inception to the demolition phase of the project, and SC manages its economic, social and environmental impacts (Ismail, Halog and Smith, 2017). According to Sfakianaki, (2019) for a sustainable building to be effective, energy consumption, reuse/recycling of materials, construction and demolition waste management, effective legal and legislative frameworks, long-term costs, efficient use of resources, environmental and economic design and awareness must be addressed. It is only when all of the main characteristics of sustainability are adhered to in a construction project that it is deemed sustainable (Mateus and Braganca, 2011). The three pillars of sustainability depicted in Figure 1, below, show how SCPs enhance the beneficial contributions to the well-being of individuals while simultaneously sustaining the sound functioning of ecosystems and social systems. Since the characteristics of building and infrastructure, processes, products, and services are largely determined through the design process, it is vital that all relevant sustainability concerns must be addressed from the beginning of a project (Gagnon, Leduc and Savard, 2012).

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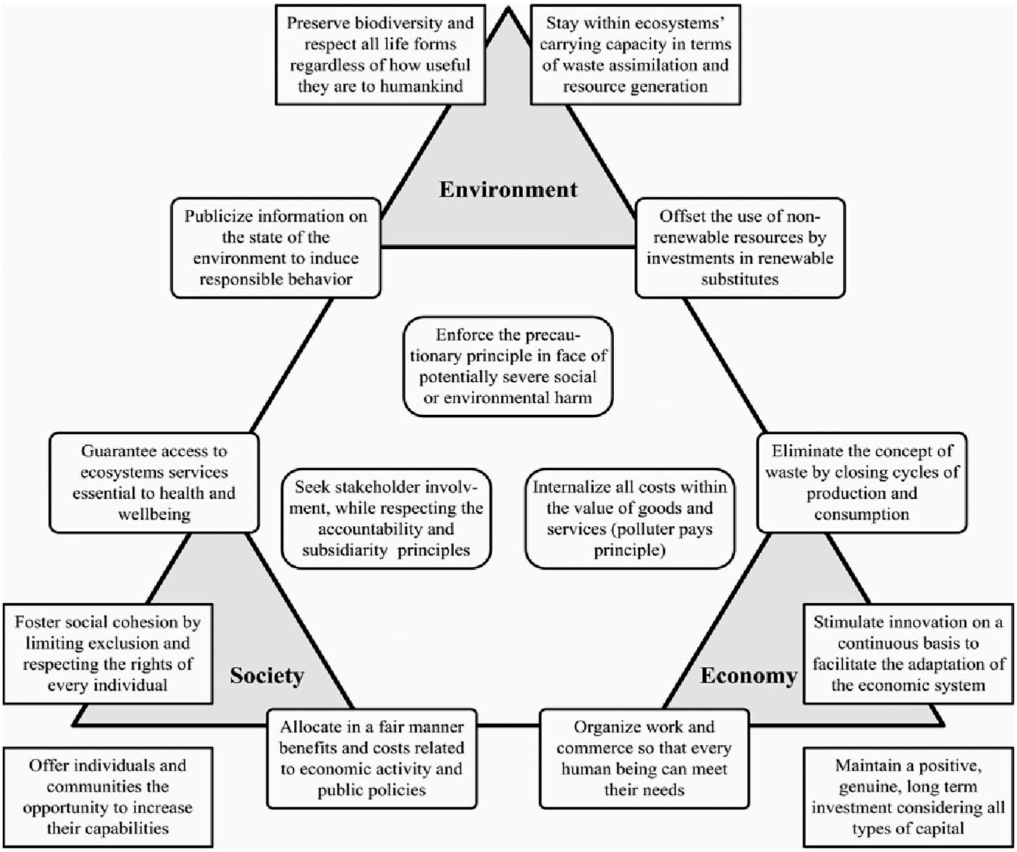

Figure 1. Sustainable construction pillars (Gagnon, Leduc and Savard, 2012).

It is therefore vital to ensure that from the inception phase to the design, construction, operation, maintenance and demolition, SC methods are adhered to that are environmentally friendly and resource-efficient throughout the building's life cycle. Despite this intention, the way we currently design, construct, and manage our building projects suggests that the construction sector has the largest potential negative effect on sustainability (RICS, 2013). The built environment professionals required to participate in these projects efficiently and profitably will need relevant competencies to ensure SC is realised.

This implies that experts in the built environment must be well-versed in SC principles in order to put them into practice. Not only are they expected to be knowledgeable, but they must also work as part of a cohesive team from start to finish, which includes the client, project manager, contractor, architects, engineers, quantity surveyor and construction managers (Djokoto, Dadzie and Ohemeng-Ababio, 2014). To execute sustainable construction, the professional team need the most up-to-date knowledge on materials and tools to use. However, Williams and Dair (2007) found that this was not the case. In their study, most stakeholder groups reported experiencing difficulties and challenges owing to lack of information regarding sustainable construction practices.

Karunasena, Rathnayake and Senarathne (2016) discovered that having good expertise isn't enough for built environment professionals if they can't successfully practice sustainable construction. Therefore, it is important to improve stakeholders' efficiency and motivation for sustainable construction by transferring and implementing sustainable concepts in terms of new methods of working, thinking, and learning (Sfakianaki, 2015; Jamil and Fathi, 2016; Schropfer, Tah and Kurul, 2017). Moreover, highlighting the benefits of built environment professionals with competencies for SCPs will also act as an eye-opener for the government and the construction industry to equip professionals for sustainable construction projects (SCPs), as they will then be able to ensure that sustainability is embraced in the sector (Osuizugbo et al., 2020). Previous studies have identified the benefits achieved by competent built environment professionals as follows:

a) ***Improved performance of the SCPs***
Adequate knowledge for SCPs will improve stakeholders' efficiency and motivation, particularly in a more technologically advanced environment with a more open workforce that allows for better communication and knowledge sharing (Shen, Wu and Zhang, 2010). The most important impacts of skilled professionals, according to Leje *et al.* (2020) are improvements in organisational performance and environmental efficiency. Furthermore, their rating of enhanced project delivery as the most important effect suggests that skilled built environment professionals had a greater influence on SCP delivery.

b) ***Adequate understanding of supervising SCPs***
Adequate understanding of supervising SCPs is a critical benefit for built environment professionals. Supervising SCPs entails: "professional competence of specialists," "collaboration with the parties involved," "use of new technologies," and "internal control systems", all of which are essential and have a positive impact on guaranteeing high-quality SC work to meet requirements for SC (Mjakuškina, Kavosa and Lapin, 2019).

c) ***Improved project management of SCPs***
Having competent built environment professionals for SCPs will result in more effective decision-making, decreased costs connected with employee turnover and litigation, higher productivity, enhanced quality delivery, improved access to a changing marketplace, improved staff retention, a broader customer base, and reduced expenses associated with turnover and absenteeism, better recruitment and retention of top personnel through improved workplace attractiveness, improved business image, development of more effective conflict management strategies in the organisation, higher group cohesion, increased resilience and flexibility, and improved creativity and innovation (Abdel-Raheem and Ramsbottom, 2016; Bendl, Fleischmann and Walenta, 2008; Shen *et al.,* 2009).

Since workers involved in the planning, implementation and monitoring processes of SCPs must be qualified, human resource capacity is critical to infrastructure performance (Willar *et al.,* 2019). Marcelino-Sádaba, González-Jaen, Pérez-Ezcurdia, (2015) said that built environment professionals equipped with competencies in sustainability and SC processes is one of the key objectives for the full implementation of sustainable development projects and sustainability. They further named possible project processes that include stakeholder management and application of building sustainability standards, use of evaluation tools and decision-making processes to ensure overall sustainability. However, these benefits were to specific built environment professionals which is coupled with limited research on the benefits of skilled built environment professionals undertaking SCPs. This paper aims to unearth the benefits the built environment professionals with competencies in SCPs in South Africa with experience in delivering SCPs.

2 METHODOLOGY

Constructivist philosophy was adopted for this research to determine the purpose of the study. A constructive research philosophy focuses on developing theories based on human experiences. The aim of this study was to identify the benefits of built environment with competencies for SCPs in South Africa. The purposive sampling technique was adopted for this research; this was due to the fact that it was designed to choose professionals that have been involved in sustainable construction projects, they should have registered with a recognised professional council/body in South Africa, and the respondents were to chiefly undertake projects in Gauteng and North West provinces of South Africa, the choice of these provinces was amplified by President, Cyril

Ramphosa's State of the Nation Address speech in the year 2020. In the speech the President indicated that "a new smart-city will be developed in Lanseria, which will be led by the Investment and Infrastructure Office in the Presidency alongside the provincial government of Gauteng and North West. In order to achieve credible sample size for semi-structured interviews a minimum sample size of between 5 and 25 is required according (Saunders *et al.*, 2016). This is also supported in the study by Tshele & Agumba, (2014).

Therefore, a total of 21 built environment professionals took part in the interviews, which were conducted using a semi-structured interview and were recorded. Because of the Covid-19 rules and regulations, the interviews were conducted over the phone. The interviews took approximately thirty minutes.

The interview schedule for this study was divided into two sections: the first section included demographic questions that required respondents to provide information about their educational background, the professional council they are registered with, the number of years they have worked in the construction industry and in undertaking SCPs, as well as the number of projects they have been involved in, while the second section focused on asking respondent questions that will help researchers identify the benefits of skilled built environment professionals when undertaking SCPs, i.e. why is it beneficial for built environment professionals to have the required competencies in executing SCPs?

ATLAS.ti version 7 was used to manage the data. Thematic content analysis was used to identify the themes and sub-themes of the benefits of built environment professionals with competencies. After analysing the 21st interview, data saturation was achieved. The research's trustworthiness i.e. validity and reliability, this was achieved by purposively sampling the participants, prolonging the engagement, asking follow-up questions and allowed participants to back up their answers with examples, recording the interviews, protecting confidentiality, providing a clear description of the study setting and assumptions that were crucial to the research.

3 RESULTS

3.1 *Socio-demographics data of the respondents*

The sociodemographic characteristics of the participants are discussed below.

Fifteen (71.4%) of the participants have a BSc degree as their highest academic qualification, five (23.8%) have a Master's degree while only one (4.8%) participant had a diploma. Nine of these degrees include engineering, five from project and construction management, four quantity surveying, three from architecture. The study participants were registered with the Engineering Council of South Africa; South African Council for the Project and Construction Management Professionals while other registration bodies for the participants include South African Council for the Architectural Profession, South African Council for the Landscape Architectural Profession and South African Council for the Quantity Surveying Profession. Seventeen (81%) of participants have over ten years of experience in the construction industry, while three (14.3%) participants have more than ten years of experience in sustainable construction projects. Only five (23.8%) participants have been involved in over ten sustainable construction projects while others have been involved in less than ten of such projects. Concerning the size of company worked for, fourteen (66.7%) participants work for small companies, two (9.5%) work for medium sized companies while 5 (23.8%) identified working with big companies.

3.2 *Benefits of built environment professionals with competencies for SCPs*

Figure 2 indicates the main and the sub-themes of benefits that were generated from the ATLAS.ti version 7. The participants identified the benefits of built environment professionals with competencies for SCPs in South Africa. The benefits identified by the participants are summarised herein: (i) sustainable solution, (ii) public health and safety, (iii) client satisfaction, (iv) efficient use of resources, (v) reputation.

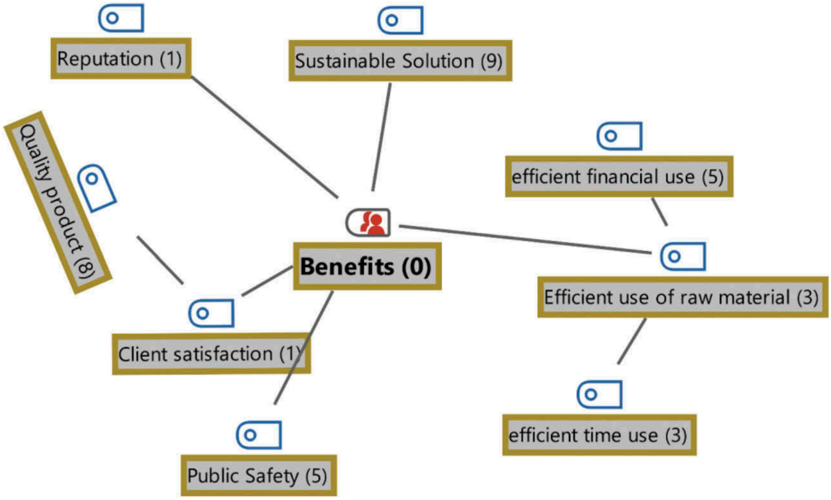

Figure 2. Benefits, Source: Field data generated from ATLAS.ti 7.

3.2.1 *Sustainable solution*

When participants were asked about the benefits of equipping built environment professionals with the required competencies for SCP. Some of the participants agreed that professionals with the required competencies for SCPs in the built environment will guarantee that the project's sustainability requirements are achieved. Such competency will ensure that *"The project will achieve the sustainability requirements, participant 14 (P14)"*, a participant mentioned. The lack of such competencies would definitely proliferate sub-standard project, like a participant mentioned that *"without competencies…they're obviously not going to deliver the sustainable project successfully (P8)"*.

3.2.2 *Public health and safety*

Participants pointed out that competencies in sustainable construction projects will help build better quality infrastructures which in turn will prevent completed construction projects that can cause harm to the people and the environment. One of the participants mentioned that the competencies would be important *"So we can be able to use correct materials and protect our environment for ourselves and the future generations (P11)"* because *"If you don't have the knowledge of what it entails …. it's harmful to the environment (P6)"*. An aspect that was also highlighted in ensuring public safety was the reduction in environmental pollution, a feat that can be achieved with such competencies just like a participant pointed out, *"It will be an advantage …there's less pollution and more recycling of materials (P12)"*.

3.2.3 *Client satisfaction*

Some of the participants believed that ensuring competencies for built environment professionals will ensure that they design and deliver quality products and services. The participants mentioned that when SC competencies are embraced by construction industry professionals the *"scope will be clearly defined (P24)"* and *"quality will not be compromised (P23)"*. However, if professionals are not equipped to carry out SC projects, *"even designs will be compromised (P8)*". The delivery of quality product also comes with fulfilling the requirements of the client. Some other participants believed that meeting clients' specifications is enabled by the built environment professionals having the right competencies. One of the respondents highlighted that *"A client will be satisfied knowing that she/he hired competent professionals (P24)"*.

3.2.4 *Efficient use of resources*

Equipping the built professionals with knowledge and skills for sustainable construction promotes their efficient use of resources including raw materials, finance and time. It would be difficult to *"implement within budget if we don't have competent professions (P24"*). When there are competent professionals, *"Projects will get finished and within the timeframe (P3)"*.

3.2.5 *Reputation*

The outcome of equipping built environment professionals which involves quality product delivery improves the reputation of the professional and the company. *"The professionals will be trusted and possibly nominated again for other projects (P24)"*. This can help to position for different type of investors both locally and internationally, but if the professionals are not equipped, the *"reputation will suffer (P5)"*.

4 DISCUSSION

The socio-economic demographics revealed that the built environment professionals who were interviewed had the necessary qualifications and professional registration in the field. Furthermore, they had worked on a number of sustainable construction projects, demonstrating their ability to recognise the benefits of built environment professionals with competencies for SCPs in South Africa.

Based on the foregoing the benefits that were identified by these professionals were: Sustainable solution. Having competent built environment professionals with competencies for SCP will enable the implementation of the environmental, economic, and social enablers that are associated with the successful completion of SCPs. This finding is consistent with the studies carried out by Chen *et al*., (2010); Jaillon & Poon (2008); and Yu & Kim (2011) where it was found that several advantages of implementing SC are "shorter construction time, lower overall construction cost, improved quality, longevity, better architectural appearance, improved occupational health and safety, material conservation, less construction site waste, lower environmental emissions, and reduced energy and water consumption".

Public health and safety which was explained by protecting the environment and people and less pollution was also identified as a benefit of having competent built environment professionals when undertaking SCPs. This finding is supported by Chen *et al*., (2010); Jaillon & Poon (2008); and Yu & Kim (2011), who discovered that the benefits of SC include better occupational health and safety and fewer environmental emissions.

Client Satisfaction for Sustainable Construction Projects. It is evident that when built environment professionals are equipped with requisite competencies, project delivery improves. They will deliver projects in accordance with the client's quality and sustainable requirements. This finding is supported by Ma *et al*., (2018) finding that the benefits of having equipped built environment professionals will assure the quality of SCPs resulting in client satisfaction.

Efficient use of resources when undertaking SCPs was also identified as a benefit of having built environment with competencies for SCPs. It can be suggested that equipping built environment professionals improves efficient use of resources which includes efficient use of finances, time, raw materials, as well as human resources. This finding is in line with Pan *et al*., (2018) who said that the construction process entails a variety of activities that have an impact on sustainability, such as "the use of energy-efficient equipment, efficient use of resources, minimisation of construction waste, the implementation of innovative technologies, involvement of multiple stakeholders, and raising knowledge and awareness about the various aspects of SC".

Finally, reputation for built environment professional and the company. It is evident that being competent to carry out SCP as a built environment professional will result in high quality product delivery, enhancing their and the company's reputation. This finding is supported by Tunji-Olayeni *et al*., (2018) who established that one of the significant benefits of SC is that it boosts the reputation of the company.

5 CONCLUSION

In conclusion, having built environment professionals with competencies for SCPs will lead to the effective implementation of SCPs, which benefit the economy, society and environment. The benefits that the construction industry will reap, as per the findings of this study, are improved public health and safety (meaning protecting the environment and people and generating less pollution), ability to meet the client's specification and deliver quality product, and efficient use of resources such as raw materials, money and time and reputation. It can therefore be inferred that the built environment professionals with the requisite competencies for SCPs will ensure successful delivery of SCPs. This study was only limited to Gauteng and North West Provinces of South Africa. Further research can be conducted in other provinces of South Africa to provide a national overview of the benefits of competent built environment professionals for SCPs.

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Infrastructure, investment and

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

The role of South African real estate investment trusts in a mixed-asset investment portfolio

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ABSTRACT: South African REITs are important to the South African economy, having grown from below R50 billion in 2004 to peak at around R435 billion by 2017, before started retracting. This paper assesses role of SAREITs by examining their risk-adjusted performance, portfolio diversification benefits and significance in a mixed-asset portfolio over 2013-2021. Total monthly returns, risk-adjusted performance and correlations were determined. This was followed by determining asset allocations and plotting efficient frontier diagrams. The findings show that SAREITs generated inferior risk-adjusted returns compared to benchmarks over 2013–2022 and offered minimal portfolio diversification benefits. Whilst this paper is not the first to provide empirical evidence on SAREITs' risk-adjusted performance, it is the first to publish empirical analysis on the extent to which SAREITs play a role in mixed-asset portfolios. This research enables practical, more informed, and empirically validated investment decision-making concerning the strategic role of SAREITs in a portfolio.

Keywords: Real Estate Investment Trusts, Mixed-Asset Investment Portfolio, Portfolio Diversification, Asset Allocation, Markowitz Portfolio Selection Model, Risk-Adjusted Returns

1 INTRODUCTION

Publicly traded Real Estate Investment Trusts (REITs), are highly sought after among investors because their underlying assets are income-producing properties which are considered stable in volatile markets. REITs are also considered the ideal investment vehicle for most everyday investors seeking exposure to real estate, high-dividend yields, total return potential, and cash liquidity. Krewson-Kelly & Thomas (2016). list several compelling reasons for investors to include REITs in a well-balanced investment portfolio, and those include liquidity, double-digit total returns, and portfolio diversification.

The introduction of REITs legislation on 25 October 2012 by the South African government ushered in a REITs dispensation which became effective on 1 April 2013. The legislation did away with the old forms of securitised real estate (Property Unit Trusts and Property Loan Stocks) and sought to create a unified tax treatment of listed property companies, to introduce more stringent regulatory requirements, and to uplift the South African real estate market to an internationally competitive level (SA National Treasury, 2007). The expected benefits from this new regime included greater liquidity and capital flexibility, high yields, and flow-through taxation (eProperty News, 2013). The REIT dispensation led to a significant growth of the real estate equities market even prior to the promulgation of the new framework. The sector, which was below the R50 billion market cap in 2004, experienced

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accelerated growth, reaching a peak of around R435 billion by 2017, and now hovering around R250 billion market cap in July 2022 (FTSE Russell, 2022). SA REIT Association chairperson also noted that since this launch, the SAREIT market capitalisation has seen exponential growth, with about 43% recorded in 2015 (Laurence Rapp, 2015). He also notes that the SAREITs was for the first time included in the global equity indices, boosting the average monthly trade to over R10 billion.

However, some empirical evidence arising from several authors (Ntuli & Akinsomi, 2016; Kubheka, 2019; Bantseke, 2018) showed that SAREITs fail to generate superior risk-adjusted performance compared to the general stock market and that the performance of REITs is more sector-specific instead of being generalised. The research findings rather advocated for property-type diversification strategies being paramount in a portfolio that involves REITs. This has raised questions in the author's mind as to the value-adding role of SAREITs in a mixed-asset investment portfolio if they underperform and cannot offer diversification benefits, especially among index investors who do not have the luxury to pick and choose the individual stocks.

Hence, the purpose of this research is to evaluate the risk-adjusted performance, significance, and portfolio diversification benefits of SAREITs in a mixed-asset investment portfolio in South Africa during the period between April 2013 and March 2022. The empirical focus of this research will endeavour to answer the three questions concerning the SAREITs:

(1) How effective is the SAREIT in outperforming the SA market and the global property market?
(2) Do SAREITs offer the diversification benefit that REITs are purported to offer?
(3) What is the risk-adjusted performance of the SAREITs in a mixed-asset investment portfolio including other sectors? This question seeks to find the optimal allocation for SAREITs in a mixed asset portfolio consisting of other equities and bonds.

By answering these questions, the author would have provided considerable insights into the added value of SAREITs in mixed-asset investment portfolios and their implied strategic role, thereof. The research findings will enable investors for both local and international, to be more informed and pragmatic in their investment decisions as this paper provides empirical evidence concerning the effectiveness of SAREITs as a viable investment vehicle into the future.

2 LITERATURE REVIEW

Although REITs are technically stocks, the underlying asset, which is real estate, is a different asset class from ordinary stocks; that is why segments of the market view REITs as real estate. As such REITs have gained popularity in recent years, as they are purported to offer the diversification benefits that real estate is known for, and above-average regular income in the form of dividends.

Internationally, changes in REIT legislation and tax reforms have popularised REITs even more; and this popularity was confirmed by a noticeable uptake of REITs amongst institutional, corporate, and individual investors, making REITs one of the mainstream investment options for mixed-asset investment portfolios. In 2013, the South African financial markets also welcomed the new regulatory framework on REITs, which sought to create a unified tax treatment of listed property companies, introduce more stringent regulatory requirements, and uplift the local real estate market to internationally competitive levels (SA National Treasury, 2007). This action was welcomed by international markets, leading to SA REITs being included for the first time, in global equity indices (Laurence Rapp, 2015). The effect of the REIT dispensation was noticeable in the volumes traded on the JSE and the rapid growth in the SAREITs market capitalisation (Laurence Rapp, 2015).

Any rational investor seeks to maximise the returns on their invested capital while trying to safeguard their invested capital in real terms. The investor's problem as it relates to REITs and mixed-asset investment portfolios lies in the selection of several assets which, when combined, offer the most desirable features concerning the expected returns and related risk (Hargitay & Yu, 1993). Ralph L. Block, in his book *Investing in REITs*, states that since real estate as an asset class is an inflation hedge due to its low correlation with other asset classes, therefore REITs as a proxy to direct real estate, can add stability to an investment portfolio (Block, 2006). Evidence from Hudson-Wilson (2001), however, shows that REITs underperformed both stocks and bonds on a risk/return basis between 1987 and 2000. Moreover, REITs have become more correlated with the stock markets, and that they do not provide a good hedge against inflation as purported. On the other hand, Frankel believes that REITs are likely to yield impressive long-term returns, especially when the price appreciation of real estate, the potential for rental income, and the integral tax benefits of real estate investing are all accounted for (Frankel, 2019).

International market data shows that REITs have become more correlated with the stock markets, and that REITs do not provide a good hedge against inflation as purported. The fact that REITs returns correlate positively with general stock market returns (He et al., 2003), and that they generally underperform other common stocks, goes against investors' reasons for investing since investors "would prefer higher returns to lower returns and lower risks to higher risks" (Hargitay & Yu, 1993). Furthermore, investors should diversify their investment portfolios, not to maximise returns, but to minimise the effects of volatility on a portfolio over time (Fidelity, 2021). A study on European REIT returns compared with those from other asset classes, including stocks, bonds, and commodities, showed a significant positive correlation between REITs and other equities, especially small-cap and value stocks (Niskanen & Falkenbach, 2010). In a USA study by Mueller, Pauley and Morrill (1994) assessing REITs in a mixed-asset portfolio, they found that REITs had similar returns to those of small-cap stocks. Kuhle looked at the effect of including REITs in a portfolio of common stocks and concluded that REITs do not add significant improvement in the Sharpe ratio (Kuhle, 1987).

A South African study found that diversified REITs exhibited a higher correlation to general stocks than sector-specific REITs, disqualifying them as a good diversification candidate in a mixed-asset investment portfolio (Akinsomi, 2022). Akinsomi rather suggested that sector-specific REITs have better diversification benefits in a mixed-asset portfolio than diversified REITs. The study by Zhou and Anderson (2012) found that the extreme risks involved in REIT markets are largely higher than those of stock markets. Hence, they concluded that the diversification benefits of REITs are sometimes not present when they are needed most.

3 RESEARCH DESIGN AND METHODOLOGY

This part aimed to answer three questions which, once answered, would fulfil the objective of the study. The author undertook an assessment of the past pricing data on the selected Johannesburg Securities Exchange (JSE) indices, downloaded from IRESS. The global property index data however was downloaded from the global property research website. All the indices that were used are all listed in Table 1, below. Then the monthly total returns were computed for the period between April 2013 and March 2022. The annualised returns and annualised volatility were also calculated. With the usage of Sharpe ratio, Sortino ratio and the Calmar ratio, the risk-adjusted returns were computed for each index.

To assess the diversification benefits of the mixed-asset portfolio, the correlation analysis was carried out together with the asset allocation and efficient frontier plots. For this purpose, the Markowitz Modern Portfolio Theory (MPT) and aspects of the Post-Modern Portfolio Theory (PMPT) were employed to construct optimal-risky portfolios. The fundamental and relevant components of MPT that relate to this research study are diversification and the efficient frontier (Pask, 2008) whilst the downside risk and Sortino ratio are components of the PMPT (Rom & Ferguson, 1993). The important formulas used are provided in the Section 3.1.

Table 1. A list of indices.

Index	Description
JSE All Share Index (J203)	The All-Share Index is a proxy for the South African market and was used as a benchmark against which the SAREITs performance was measured.
JSE SA Listed Property Index (J253 - SAPY)	This index was used as proxy for SAREITs, representing all real estate stocks with primary listing in South Africa. It is the main subject of our study.
SA All Bonds Index (ALBI)	This index represents the South African bond market. This product was launched by the then Bonds Exchange of South Africa.
GPR 250 REIT Index	This index represents the global REIT market and covers all companies with a REIT-like structure. It will be used as performance benchmark, like All-Share.

3.1 *Equations*

The list of equations below was used to calculate the metrics mentioned above.

$$\text{Portfolio StDev}\,(\sigma_{\text{annual}}) = \sqrt[2]{\frac{1}{N}\sum\nolimits_{i=1}^{N}(R_i - \mu)^2} \times \sqrt[2]{252\ days} \tag{1}$$

where N = sample size; $\mathrm{R_i}$ = each return value from the sample; and μ = the sample mean.

$$\text{Annualised Portfolio Returns} = \left(\frac{Ending\ \ Value}{Beginning\ \ Value}\right)^{1/n} - 1 \tag{2}$$

$$\text{Sharpe Ratio} = \frac{\mathrm{E(R_X - R_f)}}{\sigma_{\mathrm{X}}} \tag{3}$$

where R_X = portfolio return; R_f = Risk-free return; and σ_X = portfolio standard deviation.

$$\text{Downside Risk} = \sigma_{\mathrm{d}} = \frac{1}{\mathrm{n}}\sum\nolimits_{\mathrm{i=1}}^{\mathrm{n}}(R_X - \text{Target R})^2 * \mathrm{f(t)} \tag{4}$$

$$\text{Sortino Ratio} = \frac{\mathrm{E(R_X - R_f)}}{\sigma_{\mathrm{d}}} \tag{5}$$

$$\text{Maximum Drawdown (MDD)} = \frac{\text{Trough Value} - \text{Peak Value}}{\text{Peak Value}} \tag{6}$$

$$\text{Calmar Ratio} = \frac{\mathrm{E(R_X - R_f)}}{\mathrm{MDD}} \tag{7}$$

4 RESEARCH RESULTS AND DISCUSSION

4.1 *How effective is the SA REIT in outperforming the SA stock market and the global property market?*

The risk-adjusted performance analysis for the SA REITs is presented in Table 2. SA REIT has significantly underperformed both the South African stock market and the global property market over the nine-year period since the REIT dispensation. SA REITs also recorded the highest risk of the lot and the lowest risk-adjusted returns as measured by the Sharpe ratio

(-0.0078). Overall, the SA REITs has delivered a cumulative return of a meagre 10.18 percent whilst the global property market and the SA stock market have delivered 79.77 percent and 158.76 percent, respectively.

Table 2. SAREIT performance analysis: April 2013 - March 2022.

Asset	Sharpe Ratio	Average annual return (%)	Annual risk (%)
SAREIT	-0.0078	3.68	21.80
SA Stock Market	0.5712	11.62	13.60
Global Property Index	0.2543	7.92	16.01

4.2 *Do SA REITs offer the diversification benefit that REITs are purported to offer?*

Modern portfolio theory states that one can build a portfolio of assets that has less risk than any of the underlying assets alone. This is where correlation analysis comes into play. Correlation analysis was carried out to measure the direction and strength of linear association between any of the two assets. The correlation analysis matrix of the portfolio with respect to SA REITs is shown in Figure 1. The first noticeable finding is that all correlations are positive, with differing strengths. The highest correlation of returns is between the All-Share index and the SA REITs Index at 0.69, indicating high correlation. This means SA REITs tended to move up and down with the SA stock market in general, regardless of the changes or lack of changes in the values of the underlying properties within the SA REITs index.

Figure 1. Portfolio's correlation matrix.

The correlation of returns between the SA REITs and the SA All-Bond index is at 0.64, indicating a moderately correlation. From the literature review, REITs usually appear to be an excellent bond alternative and vice versa because the two are similar in many ways. For instance, they both produce income on a regular basis, and they are also legally required to pay out income.

The correlation of returns between the All-Share index and the SA All-Bond index is at 0.41, representing the lowest correlation of the lot. In the context of a mixed-asset portfolio, the given level of the correlation is necessary to help lower the portfolio's volatility without reducing allocations to indices, and the two assets can be a hedge for each other. These findings show that the generally held opinion that REITs have a low correlation to the stock market and other asset classes does not hold true for SA REITs.

4.3 *What is a reasonable allocation (or weight) to assign to SA-REITs in a mixed-asset investment portfolio?*

The first step in portfolio allocation was to put together an equally weighted portfolio, for which the returns, the volatility and the Sharpe ratio were calculated. An equally weighted portfolio resulted in negative risk-adjusted returns. The results are presented in Table 3. This goes to support the view that to truly optimise the portfolio, plugging in random weights is not the best possible idea. The computation of portfolio variance would need to be based on the portfolio combination that gives maximum expected returns. For this reason, the optimal portfolios were determined with the use of the Sharpe, Sortino, and Calmar ratios that are explained below.

4.3.1 *Portfolio optimisation using the Sharpe ratio*

To compute the efficient frontier and plot its graph, we ran an algorithm 25 000 times. For each iteration, the loop considered different asset weightings and calculated the risk and return associated with the individual portfolio combination. At any given iteration, the sum of the weights added up to 1 or 100%. In computing the Sharpe ratio, the author assumed a risk-free rate per 3.85 percent per annum. Of all the portfolios on the efficient frontier, of interest was the portfolio with minimum volatility since it has the lowest level of risk, and the maximum Sharpe portfolio which has the highest Sharpe ratio. These are presented in Table 3, and all the returns and volatilities were plotted on a 2-dimensional graph, giving the efficient frontier for the given portfolio, as shown in Figure 2.

The red star on the graph denotes the most efficient minimum volatility portfolio, while the green star denotes the most optimal-risky portfolio (maximum Sharpe portfolio) as shown in Table 3.

Table 3. Efficient portfolios based on the Sharpe ratio.

Portfolio Type	Sharpe Ratio	Annual Return (%)	Annual Volatility (%)	All Share Index (%)	SA Listed Property (%)	All Bond Index (%)
The equally weighted portfolio	-0.5553	-0.2441	07.373%	33.333	33.333	33.333
The minimum volatility portfolio (% weights)	-0.0322	-0.049	09.084%	16.01	0.1429	83.85
The maximum Sharpe portfolio (% weights)	0.0599	4.8958	17.4418%	99.145	0.4203	0.4344

Regarding the allocation of assets to the portfolios, from Table 3 we learn that the minimum volatility portfolio allocated most of the investment to the SA All-Bond Index as this is the asset with minimum volatility, and the SA REITs received the least allocation among the three indices. However, with the maximum Sharpe portfolio, the All-Share Index received 99 percent of the allocation, while the other two receiving only one percent, and SA REITs receiving the least share of the allocation.

4.3.2 *Portfolio optimisation using the Sortino ratio*

With the use of the downside standard deviation, the portfolios were randomly generated, and each portfolio's Sortino ratio was computed. In the same way as Sharpe ratio computation, thousands of portfolios were randomly generated. Of interest was the two special case portfolios which are, the minimum downside standard deviation portfolio and the maximum Sortino ratio portfolio.

The minimum downside standard deviation portfolio is presented in Table 4, and is depicted by the red star in Figure 3 which shows a negative return, making it undesirable for investors. The maximum Sortino portfolio is the most optimal-risky portfolio and is depicted by the green star in Figure 3. It has a positive ratio and a relatively higher return in comparison to the other portfolio, thereby making it more attractive than the minimum DSD portfolio.

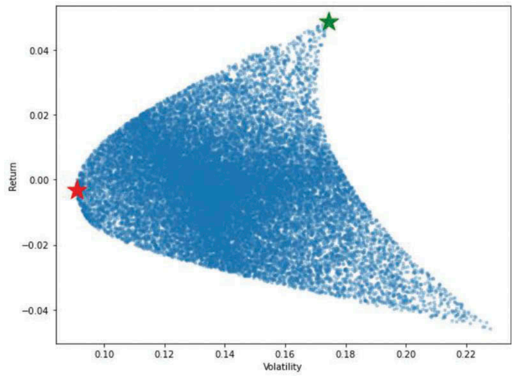

Figure 2. Sharpe-based efficient frontier.

Table 4. Efficient portfolios based on Sortino ratio.

Portfolio Type	Sortino Ratio	Annual Return (%)	Annual DSD (%)	All Share Index (%)	SA Listed Property (%)	All Bond Index (%)
The minimum DSD portfolio (% weights)	-0.2566	-2.205	8.591	3.9669	0.3596	95.674
The maximum Sortino portfolio (% weights)	0.4566	6.695	15.94	98.8147	0.2949	0.8904

Looking closer at the weights and the risk-adjusted performance of these two special case portfolios, significant differences in their downside volatility, returns, and asset allocations are noticeable.

With respect to the weight allocations, it can be observed from Table 4 that the minimum downside standard deviation portfolio allocated most of the investment to the SA All-Bond Index whilst the SA REITs Index received the least weight allocation of all the three assets. However, with the maximum Sortino portfolio, the All-Share Index received most of the weight allocation, and yet again, the SA REITs received the least weight allocation. Both metrics confirm that SA REITs is not as desirable as the other assets on the risk-adjusted basis.

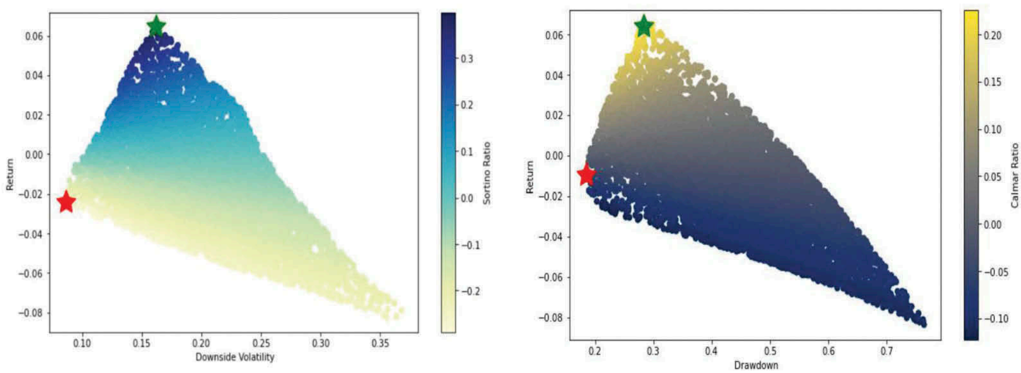

Figure 3. Graphs showing the efficient frontiers for the Sortino ratio and the Calmar ratio.

4.3.3 *Portfolio optimisation using the Calmar ratio*

Any reasonable investor would prefer a low maximum drawdown since this translates into minimal investment losses (Hayes & Scott, 2020). From Table 5, the minimum drawdown portfolio had a lower Calmar ratio of minus 5.703 percent with negative portfolio returns, suggesting that the drawdown risk is higher.

With respect to the asset allocation, more weight was allocated to the All-Bond index, exceeding 83 percent, followed by the All-Share Index at 16 percent, and the SA REITs lagging far behind at less than one percent of asset allocation. On the other hand, the optimal-risky portfolio had a high Calmar ratio of positive 0.22 and a portfolio return of 6.35 percent, indicating that the portfolio's return had not been at risk of large drawdowns.

Table 5. Efficient portfolios based on the Calmar ratio.

Portfolio Type	Calmar Ratio	Annual Return (%)	Annual Volatility (%)	All Share Index (%)	SA Listed Property (%)	All Bond Index (%)
The minimum Drawdown portfolio (% weights)	-0.5703	-1.059	18.566	16.041	0.1377	83.821
The maximum Calmar portfolio (% weights)	0.2234	6.366	28.499	95.491	0.581	3.929

The asset allocation of the portfolio with the highest Calmar ratio favoured the All-Share Index with an allocation of more than 95 percent, followed by the All-Bond Index at 3.9 percent and with the remaining 0.5 percent allocated to the SA REITs. The portfolios are visualised in Figure 3, where the red star represents the portfolio with the minimum drawdown and the green star is for the portfolio with the maximum Calmar ratio.

Among investors and traders, a Calmar ratio of more that 1 is preferred; if it is 3 and above, it is an excellent investment. For our scenario, the maximum Calmar ratio is only 0.22. For the investor to optimise his or her investment, most of the allocation should be in the All-Share Index, and very little in real estate.

4.4 *Discussion*

This paper examined the role of SA REITs in a mixed-asset investment portfolio, with a specific focus on diversification benefits and the risk-adjusted performance. The data showed that the SA REITs have been underperforming both the south African stock market as well as the global property market by a significant amount. The raw data points to a moment in 2017 when the SA REITs market started a downward trend. There are other reasons which need to be investigated beyond the scope of this research.

Secondly, the SA REITs tended to move up and down with the broader stock market, regardless of the changes or lack of changes in the values of the underlying properties within the SA REITs. This finding indicates SA REITs is highly correlated to the general stock market. As such, the generally held opinion that REITs have low correlation to the stock market and other asset classes does not hold true for South African REITs. The findings suggest that SA REITs do not offer any diversification benefits and cannot be used for diversification purposes. Investors will need to be clear about the reasons for incorporating the SA REITs into their mixed-asset investment portfolios as the research results show that it cannot be for diversification purposes.

Literature review indicated that REITs generally generate superior performance in comparison to other asset classes, even in the face of high interest rates, with only a small fraction experiencing diminishing returns when interest rates move in the upward direction. The evidence from the USA suggested that REITs generally performed better than the S&P 500 (DiLallo, 2020). A consensus in international markets is that REITs generally perform better than other stocks, even during periods of slow economic growth. However, evidence from South Africa shows that local REITs were found to underperform the South African stock market and the bond market for the period.

In getting to allocate assets objectively, three tools were employed to give better insights of the risk/return relationship. These tools were the Sharpe ratio, the Sortino ratio and the Calmar ratio. Overall, the All-Share Index provided the best risk-adjusted returns, hence the highest allocation ranging between 95 and 99 percent. The second-best performing asset was the All-Bond Index, with allocations ranging between 0.4 and 4 percent, which could be attributed to the Index's diversification benefits. The SA REITs Index was found to have the least risk-adjusted returns, with its allocations ranging between 0.2 and 0.5 percent from all the three tools. The data and analysis have not provided evidence of the much-anticipated positive impact of the REIT dispensation in South Africa. Rather, the SA REITs has been on a downward trend over the last half-a-decade.

5 CONCLUSIONS

The data analysis process started by testing the efficacy of SA REITs in generating returns that exceed the market benchmarks, the local stock market and the global property market. The study has showed that the SA REITs failed to perform above the benchmarks since the REIT dispensation. The study went further to employ the MPT and PMPT frameworks to allocate capital to optimal portfolios made up of three asset classes, with the intention to determine an objective and fair allocation of each asset in a portfolio. The allocations were based on each asset's risk-return profile and diversification benefits. Three types of portfolios were created: equally weighted, minimum volatility, and optimal-risky. The efficient frontier combinations were constructed according to the minimum volatility parameter, as well as the ratios (i.e., models) that seek to optimise the risk-return trade-offs. With all the three models based on minimum volatility, SA REITs received the least allocation in the mixed-asset investment portfolio. When the models were rerun to consider portfolios where the ratios were at their maximum, SA REITs had the least allocation again – of less than one percent – in an optimal mixed-asset investment portfolio. In both the minimum volatility and maximum ratio portfolios, SA REITs do not have a significant allocation in optimal portfolios because they are highly correlated with other assets, and they carry the highest risk while offering mediocre returns.

The findings from this study contradict the international studies that found REITs have a significant role to play in a mixed-asset investment portfolio, especially regarding portfolio diversification and generating superior risk-adjusted returns. Investors who are looking to maximise their returns should look at alternative asset classes to SA REITs or do minimal allocation to SA REITs. In the event an investor is seeking real estate exposure through SA REITs, investors are cautioned to consider other reasons beyond diversification and superior risk-adjusted returns. And it is also possible that that timing might be off, for the REITs market which has been on a downward trend for the last five years.

Further research is recommended to investigate the effects of the country's credit rating on REITs, since the period when SA REIT index started going down coincided with SA credit rating was for the first time in a long time dropped to sub investment. Another possible research area relates to real estate business cycles, as some views suggest the real estate market is on a downward trend which is a phase in real estate business cycles.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Examining prospects of stakeholders' integration in rural infrastructure investment interventions to aid sustainable rural livelihoods

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ABSTRACT: Colonial and apartheid entrenched spatial form in the global south is characterised by inadequate infrastructure to facilitate Sustainable Rural Livelihoods. Fragile public institutions responsible for service delivery coordination often struggle to create an enabling environment for transformation of previously marginalized rural communities. This paper investigated the extent to which Regional Development interventions aided Infrastructure Investments towards transformation of rural space economy in previously marginalised communities. Case Study approach was employed where six case study projects were examined following comparative and thematic analysis. Challenges, limitations and success factors were profiled. Findings suggest that there is no meaningful Stakeholders' Integration through infusion of Collective Strategy Formulation linked to an investment framework for rural infrastructure development. Nor is action based research factoring local context being prioritised before projects are commissioned. Effectively, rural Infrastructure Investments Stakeholders Integration in accordance to local context is recommended.

Keywords: Infrastructure Investment, Regional Development, Stakeholders' Integration, Sustainable Rural Livelihoods

1 INTRODUCTION

Rural communities in South Africa continue to be epicenters of poverty, unemployment and inequality due to lack of meaningful economic opportunities (Gumede, 2021; Du Toit, 2017). Despite prevailing circumstances on the ground, there seems to be continued urban bias approach to development planning, evident through a strong drive towards creation of smart cities within the context of urban growth management (Van Rooyen, 2022; Van der Hoogen, et al., 2019). Arguably, urban agglomeration through establishment of Metropolitan Cities have also been the preferred approach as opposed to Regional Integration that seeks to find a balance between Urban Growth Management and Sustainable Rural Livelihoods. Moreover, less emphasis has been put on Regional Development to enable effective management of rural-urban interphase and transformation of rural space economy through effective Infrastructure Investments anchored through Regional Integration beyond administrative boundaries. Though often neglected, rural communities remain untapped hotbeds for innovations.

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In contrast, urban growth management orientated development continue to take centre stage and receive more investments opportunities at the expense of transformation of the rural space economy (Mbatha *et al.,* 2021). Accordingly, prevailing socio-economic challenges cannot be divorced from lack of infrastructure investments to aide sustainable rural livelihoods, particularly in regions that are predominantly rural and were created through segregation policy and legislative frameworks in South Africa's colonial and apartheid eras.

The need to find innovative strategies to respond to ever-growing issues of poverty and socio-economic disparities in South African rural towns and communities cannot be ignored (Ramaano, 2021). Notably, Infrastructure Investments are critical in ensuring functionality of regions as they help facilitate spatial integration and socio-economic prosperity (Schindler & Kanai (2021). For South Africa, the colonial and apartheid entrenched spatial form is such that there is inadequate infrastructure development to foster transformation of the rural space economy. Observations by various Scholars (Mbatha et *al.,* 2021; Qumba, 2021; Ramaano, 2021; Thacker *et al.,* 2019; Calderon *et al.,* 2018) suggest that fragile public institutions that are tasked with the responsibility of managing service delivery coordination in rural communities often struggle to effectively and efficiently create an enabling environment for sustainable rural livelihoods characterized by socio-economic prosperity. Hence this paper explored prospects of Regional Integration by fragile public institutions to collaboratively plan for and rollout infrastructure investments in a manner that facilitates transformation of the rural space economy and aid sustainable rural livelihoods, characterized by socio-economic prosperity in previously marginalized rural communities.

2 INFRASTRACTURE DEVELOPMENT FOR RURAL DEVELOPMENT SUPPORT

Inadequate infrastructure provision often compromises sustainable rural livelihoods as functionality of communities is dependent on telecommunication and transport infrastructure as well as access to adequate bulk services such as water, sewer, electricity and waste management (Thacker *et al.,* 2019). In the global south, socio-economic disparities, lack of economic growth and overall development needs and challenges are linked to infrastructure deficiencies that are prevalent and persistent (Calderon *et al.,* 2018). Seemingly, while the world press towards the forth industrial revolution, limitations of infrastructure development in rural communities remains and leave much to be desired. It is becoming evident that rural communities (particularly in the global south) are often neglected or left behind in global development agendas as they still lack the very basic infrastructure provision, let alone telecommunication infrastructure to support a drive towards Forth Industrial Revolution (4IR). This is noted while sustainability of rural communities is critical for overall poverty alleviation and socio-economic transformation towards attainment of Sustainable Development Goals (SDGs) as socio-economic disparities are mostly prevalent in rural communities. Even in South Africa, poverty is mostly affecting people in rural communities and those who migrate from rural communities in search for better opportunities urban areas.

2.1 *Rural economic development*

Rural economic development often received less recognition compared to urban development strategies for cities, towns and regions, at least until the 18th century (Cloke *et al.,* 2006). Prior to that paradigm shift, rural areas were often a source of raw materials for modernization and macro-economic production in urban areas as well as international export, which resulted in most rural communities remaining poor whilst being an important contributor to economic viability of urban areas. According to Kitchen and Marsden (2009), Rural Economic Development is centered around natural and ecological attributes which forms a backbone for rural economic activities such as tourism, agriculture, forestry, natural landscape and biodiversity, natural water features (inland and costal), mining and quarrying as well as renewable energy prospects. The emphasis is having innovative, eco-friendly approaches to preserve the natural environment while also taking advantage of the natural and ecological attributes to create sources of income for local communities. In the same vein, Saraceno (1994), emphasizes diversification of rural economy to ensure effective management of rural-urban interphase spaces while mitigating against negative rural-urban migration due to lack of economic opportunities in rural areas. Marsden (2006) notes that instead of substantial farming being seen as an alternative approach for sustainable rural livelihoods, it is often seen as unplanned/problematic farming. Effectively, commercial farming often become a dominant feature at the expense of substantial farming which plays an important role in poverty alleviation in rural communities.

3 METHODOLOGICAL APPROACH

The case study approach to data collection and analysis was employed where at least six variable case studies of various Rural Infrastructure and Economic Development initiatives were examined and subsequently analysed through comparative and thematic analysis. Agri-Parks Programme introduced by the then Department of Rural Development and Land Reform in 2015 was used as the main case study where six Farmer Production Support Units (FPSUs) case studies were identified and examined following the Schumpeterian Theory of Economic Development golden principle of multiple stakeholders' integration towards a common goal to aid economic development. FPSUs are one of three core components of South Africa's Agri-Parks concept introduced in 2015. FPSUs were used primarily because they are a component of Agri-parks that has been rolled out in Kwa-Zulu Natal where the study focused. The City of uMhlathuze Municipality within King Cetshwayo District was used as a potential study areas' regional center as it is earmarked by the Kwa-Zulu Natal Provisional Spatial Development Framework as a Regional Development Anchor. Key Informant interviews with interdependent stakeholders such as local farmers and government officials coupled with desktop review of resource and statutory planning documents namely Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs), project specific reports and articles relevant to sampled FPSUs were used for primary and secondary data collection. Foundational principles of Schumpeterian Theory of Economic Development were critical in conducting comparative analysis to identify patterns, challenges, success factors and level of integration for opportunities beyond administrative boundaries.

The study examined the extent to which stakeholders collaborate in rural infrastructure investments and whether or not planning of rural economic development and infrastructure development is confined within administrative boundaries. The analysis technique followed was qualitative in nature, centered around narrative analysis where data was coded followed by identification of themes, patterns and relationships taking into account dynamics of multiple stakeholders and scenarios associated with each case. Data was scrutinized to identify common key words and phrases, comparisons were then made between primary and secondary data. Insertions of missing elements of the subject matter were incorporated within the context of the existing body of knowledge and the Theory of Economic Development. Deliberations and conclusions were cross-referenced by considering research phenomena similarities, common trends and differences in the existing body of knowledge. Findings were then summarized and linked to study objectives focusing on regional integration in quest for transformation of rural space economy. Collective Strategy Formulation by interdependent municipalities beyond administrative boundaries was explored with the aim improving capital investments and institutional stability amongst rural municipalities with infrastructure deficiencies. Challenges, limitations and success factors were profiled in relation to the impact of Regional Development initiatives in fostering stakeholders' integration on infrastructure investment to aide Sustainable Rural Livelihoods.

4 COMPARATIVE ANALYSIS OF RURAL DEVELOPMENT INITIATIVES

The study considered Agri-Parks initiatives under the KwaZulu Natal former Zululand Homeland that were seen as an initiative that sought to bring about regional integration at District

Municipality level to aid transformation of the rural space economy. These initiatives were meant to contribute to socio-economic prosperity and Sustainability of Rural Livelihoods. Revelations from key informant interviews were such that though this was a nationwide initiative, there was no approved policy guideline informed by appropriate research, instead it would seem that it was more of a trial and error or tick box exercise as these are no longer at the fore front of Government Development Agenda for rural communities' despite being only introduced in 2015. Of late, Government seems to be perusing a new agenda of District Development Models. The sentiments from Key Informant interviews were such that this is not a surprise since before Agri-parks, there was Comprehensive Rural Development Programme (CRDP) which also yielded minimal impact on socio-economic transformation. There seems to be introduction of different flavors of plans as part of each political term of office without meaningful impact through creation of sustainable rural economic opportunities. Arguably, this is duplication without difference as there are hardly sustainable regional infrastructure investments to aid socio-economic transformation and Sustainability of Rural Livelihoods while socio-economic disparities in rural communities persist.

Though Agri-Parks Concept consist of three components namely: Farmer Production Support Units (FPSUs) which are small scale farming or agricultural industries across a District (region); Agri-hubs which are large scale agricultural industrial parks for produce from the FPSUs; and Rural-Urban Market Centres. FPSUs target specific commodities or commodity producers based on available local resources where various producers collaborate at a local municipality level. In an Agri-hub, production equipment and material is stored, sold, leased and repaired for local famers and may include fuel supply and packaging of produce from FPSUs within a district before being distributed to identified markets. Then the Rural-Urban Market is considerable an information and distribution centre to local market (local and district municipality level), domestic market (South Africa and provincial wide) and international or export market (outside South Africa). Effectively, there must be appropriate and well researched value-chain on how produce from FPSUs will be distributed to different, suitable markets while appropriate infrastructure must be in place to ensure seamless movement of goods and services as well as communication between FPSUs, Agri-Parks and Rural-Urban Markets and their clientele. Nonetheless, findings suggest that here is hardly a well-rounded policy research despite these programs being linked to the South African socio-economic transformation agenda that was initiated as part of the Reconstruction Development Programme in 1994 and subsequent government white papers focusing on poverty alleviation, reducing unemployment, bridging the inequality gap and improving service delivery.

The six (6) sampled case studies whose functionality and adequacy of support infrastructure was examined, including level of stakeholders' integration to ensure seamless value chain and operations, all received government funding. These case studies are in King Cetshwayo District (Clanso FPSU within uMhlathuze Municipality, Nsuze and Nkungumathe FPSUs both in Nkandla Municipality), uMkhanyakude District (Ndumo FPSU in Jozini Municipality and Hluhluwe FPSU in Big Five Hlabisa Municipality) and Zululand District (Bululwane FPSU in Nongoma Municipality). Their primary objective was to bring together cooperatives and small scale farmers according to their varied produce such as livestock farming, crop, fruits, plant, grain and cotton production. Ideally, they should be linked to target markets facilitated through government support. Nonetheless, little consideration was given to investigating distribution channels for national and international markets. The only market that is effective, though with its own challenges is local market. In King Cetshwayo District there is a fresh produce market in Ngwelezane within uMhlathuze Municipality. Even this fresh produce market has not been fully operational for more than two years, leading to local farmers and cooperatives resorting back to substantial farming while trying to identify other markets and distribution channels. Not much can be said about other FPSUs distribution channels beyond local market as there is no concreate value chain process plan to ensure business sustainability and economic viability.

Nonetheless, these initiative did benefit local communities and small scale farmers with irrigation infrastructure, feedlots construction, provision of office space for managing FPSU operations and security personnel, fencing, construction of tractor and implements sheds and to some extent training facilities, ablution facilities, renewable energy and electricity installations. There was also a component of supply of materials and farming equipment coupled with limited presence of business incubators to support local farmers (Madlala, 2018). Furthermore, FPSU sites examined are accessible, though regional integration infrastructure is not in place to ensure that market scope is broadened across the three Districts and beyond, i.e. domestic and international market.

4.1 *Collaboration for transformation of rural space economy: Agri-Parks implementation*

The then Department of Rural Development and Land Reform (DRDLR) was the department responsible for driving and facilitating Agri-parks programme in collaboration with National Department of Agriculture [now one department, i.e. Department of Agriculture, Land Reform and Rural Development (DALRRD)]. Close relations were maintained with provincial government, particularly KwaZulu Natal Department of Cooperative Governance and Traditional which provide development facilitation and support role to rural municipalities. A National Agri-Parks Advisory Council was established which worked with District Joint Operational Committee (DJOC) and local based Councils of Stakeholders (CoSs). The main role of a DJOC was identification of FPSU site and thereafter, actual implementation programme was managed by DALRRD Units such as Spatial Planning and Land Use Management (SPLUM) for spatial planning technical support, Rural Infrastructure Development (RID) for infrastructure development components and Rural Enterprise and Industries Development (REID) for enterprise development, training and support programmes. Since there was no specific policy research taking into account contextual dynamics to guide districts or regions, lessons had to be learned along the way and possible adjust and adapt implementation strategies. However, lessons have hardly been documented and not enough progress has been made beyond site identification, construction of FPSUs, supply of materials and equipment as well as training facilitation.

Findings suggest that there is still no meaningful stakeholders' integration through infusion of Collective Strategy Formulation coupled with coordinated multiple stakeholders' investment framework. Nor is action based research that considers local context being prioritized before projects and programmes are commissioned. Municipalities would often identify local cooperatives and potential sites as part of their agricultural support programme and submit to DJOCs and DALRRD where project proposals would be assessed and granted funding. Some of the sites used as FPSUs were already operational before Agri-parks were conceived as rural socio-economic transformation intervention strategy. The Agri-parks funding mainly assisted them to improve their operations and get more resources. There was still no multiple stakeholders' investment framework aligned to a concrete policy framework or plan. Instead, the main source of funding was from DALRRD and most things that are in place were attained through DALRRD funding. Hence it is impossible to conclude that there is meaningful stakeholders' integration on infrastructure investment to support regional initiatives such as Agri-parks. Evidently, planning and coordination of Agri-parks is confined within boundaries of a district, despite a potential for delineating Functional Regions beyond district administrative boundaries given similarities and interdependent nature of some FPSUs across neighbouring districts. Collaboration amongst FPSUs of common interest will arguable improve their marketability, capabilities and competitiveness for domestic and international markets.

Notably, the interconnectedness and interdependent nature of stakeholders in development planning and infrastructure investments for socio-economic transformation have been globally recognized as essential (Lincon, 2020; Siyongwana & Chanza, 2017). Similarly, Musvoto, et al. (2016) and observes that Spatial planning has been unable to single-handedly bring necessary changes on the ground while regional development strategies have been confronted with numerous challenges on implementation due to a significant gap between intent and execution linked to lack of meaningful stakeholders' integration. Emanating from this is a call for collaborative planning processes geared towards a Collective Strategy Formulation and mobilization of resources by interdependent stakeholders. Thus, there is a need to group neighbouring rural municipalities or towns identified within a defined functional region to cooperate internally and compete externally.

4.2 *Impact of limited rural infrastructure investments and lack of policy research*

South Africa's Rural infrastructure investments to aide socio-economic transformation and sustainability of rural livelihoods have hardly followed action-based policy research. In cases where there have been some glimpses of it, its limited and mainly tick-box exercise by public institutions or development agencies. Situations on the ground suggest that a tale of two cities and spatial inequalities are still being indirectly perpetuated due to lack of regional integration and innovative mechanisms for the management of rural-urban interphase (StatsSA, 2018). Arguably, Rural economic development cannot be looked at in isolation from urban growth management. Central to rural economic development is creation of a value-chain through agro-processing and agri-indistries within rural communities and urban rural interphase spaces, providing a clear identity of rural towns and communities (Overton & Murray, 2011). Such could be complemented by a vibrant informal economy towards poverty alleviation through subsistence/self-sustainability economic activities as a contributing factor in transformation of rural space economy (Willis & Campbell, 2004). A notably outcry from study participants was a minimal effort towards improving Rural ICT infrastructure to ensure that rural businesses are also able to improve their business operations through use of internet of things towards fourth industrial revolution (4IR).

5 POLICY IMPLICATIONS: REGIONAL INTEGRATION & RURAL SPACE ECONOMY

Though there is still a search for comprehensive strategies, transformation of the rural space economy is at least getting recognition in development planning agenda as an alternative to approaches that often favor urban growth management. Given the study findings, lack of clear direction for rollouts of Agri-hubs and limited, yet inconsistent Rural Urban Markets is testimony to common challenges that persist while government continue to introduce investment programmes without appropriate policy research to inform practice. Seemingly, government is committed to availing budget for rural infrastructure investments with minimal focus on policy research to consider local dynamics or context and thereafter craft appropriate value chain mechanism, including identification of integration zones where Agri-hubs and/or Rural-Urban Markets can be located. Arguably, the most agreeable approach by study participants is creation of Integration Zones informed by feasibility studies and market research. Integration Zones can be host to business development agencies and incubators to support local producers and facilitate trade at domestic and international levels while ensuring adherence to quality standards.

Lack of Infrastructure development due to uncoordinated infrastructure investment initiatives at regional level is considerable a contributing factor to rapid rural-urban migration and associated land use and land development complexities. This necessitate more focus on rural economic development geared towards Socio-economic Prosperity and Sustainability of Rural Livelihoods. The need for self-sustainable rural communities characterised by economic opportunities and quality of life cannot be over emphasized, though prevalent infrastructure deficiencies make it difficult for rural communities to rise above their challenges. Rivza and Kruzmetra (2017) observe that innovations in rural space economy linked to development planning governance structures is critical in ensuring viability of rural communities through collaborative planning. Seemingly, appropriate infrastructure investments are dependent on institutional capabilities. Hence it is no surprise that fragile local municipalities that are predominantly rural often struggle to bring about required infrastructure development in support of rural economic development agenda. Thus, making it essential that regional integration strategies are considered to ensure collaboration amongst municipalities that have vast rural areas with common interests and challenges.

As already deliberated in this paper, rural development programs and infrastructure investment initiatives are hardly informed by scientific policy research that leads to sustainable projects. They are often introduced as part of parliamentary budget speeches without well researched implementation plans and are hardly reviewed before new ones are commissioned. Saraceno (1994), observes that spatial differentiation is essential when dealing with development and transformation of rural space economy while ensuring diversity in the rural economic activities. There is a need to clearly identify economic strengths and opportunities of varied rural communities and formulate integration zones and economic hubs that will be part of a well-defined Functional Region, spatially configured based on functionality and economic potential, even if it means going beyond administrative boundaries. This cannot be achieved without meaningful effort to break new grounds through adaptive approaches to governance systems, market/business orientation and social formations in policy development and implementation (Kitchen & Marsden, 2009; Marsden 2004). This necessitate institutional arrangement for a regional policy approach where rural communities with common economic attributes can collaborate to form a strong economic base.

5.1 *Spatial planning systems and stakeholders integration beyond administrative boundaries*

Systems and processes associated with development programs and policies across South Africa's three spheres of government are often divorced from realities of rural communities as they are not informed by authentic research that contextualize local dynamics (Khambule, 2021). Land tenure complexities, particularly in areas under traditional authorities can also constrain investment drives and efficacy of municipalities in facilitating development for prosperous rural communities if there are no institutional arrangements in place (Marrengane *et al.,* 2021). Not enough has been done to improve engagements of Traditional Authorities in development planning and infrastructure investment initiatives beyond their involvement in Municipal Council Decision Making Structures (Louw, 2021). Consequently, rural development in traditional authority areas happen in an uncoordinated manner, leading to these areas becoming less marketable and economic development happening in a snail pace. Even infrastructure deficiencies and associated challenges of poverty and unemployment are so prevalent in areas under traditional authorities. This is also evident through rapid rural-urban migration in search for better economic opportunities, indirectly perpetuating informal settlements and socio-economic disparities in urban areas.

To sustain economic viability of rural communities, the need to broaden target market scope and ensure that client base is increased cannot be overemphasized. Functional Regions beyond administrative boundaries can help facilitate stakeholders' integration where rural municipalities and traditional authorities collaborate in a functional region to form strong economic bases where they can cooperate internally (local market) and compete externally (domestic and international markets). In South Africa, legislative instruments are already in place to enable such regional stakeholders' integration and engagement. The Spatial Planning and Land Use Management Act, (Act 16 of 2013) calls for Regional Spatial Development Frameworks (RSDFs), which can be enacted beyond demarcated administrative boundaries. Platforms such as IDP indabas would then allow for neighboring municipalities (even across districts) and government departments to work together in their planning endeavors, particularly for rural infrastructure development projects which can be very costly. Thus, meaningful effort must be put towards formulating Functional Regions with implementable regional plans and strategies beyond administrative boundaries.

5.2 *Effective management of rural-urban interphase spaces*

Transformation and viability of rural space economy is critical for urban growth management where people can have economic options in rural areas anchored through adequate infrastructure development (Gibbs, 2000). Effectively, sustainability of rural and urban areas cannot be divorced from effective management of rural-urban interphase which is arguable critical for both Sustainable Rural Livelihoods and Urban Growth Management (Gebre & Gebremedhin, 2019). Economic benefits for both urban and rural communities from economical viable rural-urban interphase spaces is such that rural communities will not only become exporters of raw materials to sustain urban communities but also active participants in the economic value chain processes. Urban-rural interphase spaces should be earmarked for agro-processing and other industrial activities for beneficiation of raw materials extracted from rural communities. Such can help create economic value chains to the benefit of rural communities where raw materials are extracted and farmed, leading to beneficiation activities in close proximity to rural communities, making them still active participants and beneficiaries of beneficiation processes. Thus, creating employment and entrepreneurship opportunities beneficial to both rural and urban communities.

6 CONCLUSION

This study explored the nexus of regional stakeholders' integration and effective management of rural infrastructure investments for creation of viable economic hubs towards sustainable rural livelihoods and proper management of urban-rural interphase spaces. The focus was on exploring alternative institutional arrangements without being fixed to administrative boundaries. Creation of Functional Regions was identified as potential solution to prevailing circumstances of socio-economic disparities that fragile rural municipalities struggle to cope with. Regional integration can help improve economic viability, domestic and international competitiveness while paving a path for some economic value chain systems and processes through creation of agro-processing industries instead of producing for local markets and export of raw materials only. Regional integration will also enable FPSUs to benefit from collaboration of local resources by local producers to enable externally competitiveness (i.e. in domestic and international markets). There is already a legislative framework to help facilitate regional integration beyond demarcated administrative boundaries through RSDFs in terms of SPLUMA. The paper recommends meaningful stakeholders integration through regional collaboration in rural infrastructure investments initiatives to contend with infrastructure deficiencies and create viable value chain systems and processes linked to rural-urban interphase spaces, thereby enabling rural Socio-Economic Prosperity and Sustainability of Rural Livelihoods. The RSDFs could be used as a mechanism to facilitate regional integration through creation of Functional Regions to guide infrastructure development in a manner that enables multiple stakeholder investment frameworks through collaboration of resources.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Performance of public sector joint venture construction projects in Zambia

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ABSTRACT: Formation of Joint Ventures (JVs) among construction companies has in the recent past become one of the vehicles used to address project delivery challenges in the Zambian construction sector particularly on large complex projects. The aim of this study was to establish factors affecting project performance on public construction joint venture projects in Zambia. Due to the limited number of JV construction projects, purposive and snowball sampling techniques were used to select the sample size which constituted all 10 registered JV projects by the NCC. The study revealed that, payment delays by clients, suspension of works, lack of commitment, inadequate partner skills, poor communication, lack of cooperation, lack of trust and unfair JV agreement were found to be the major factors negatively affecting project performance on public JVs in the Zambian construction industry. The study recommends a deliberate platform that will formally derive benefits of JVs to stakeholders.

Keywords: Construction, joint venture, project performance, factors

1 INTRODUCTION AND BACKGROUND

The construction industry is fragmented in nature because it comprises large numbers of stakeholders such as owners (clients), contractors, consultants, stakeholders, and regulators. In spite of this fragmentation, the industry plays a significant role in the improvement and accomplishment of society's objectives. According to Hatema et al. (2022), construction is one of the largest industries and contributes to the Gross National Product (GNP) in both industrialized and developing countries. Zambia is no exception because the local construction industry is one of the main sectors supporting national economy. The (Bank of Zambia, 2021) report states real GDP rebounded, rising to 3.6 percent in 2021 after contracting by 2.8 percent in 2020. This rapid growth was triggered by governments initiative to invest 25% of its budget on infrastructure development. Despite the increase in the GDP contribution, the ZCI still faces challenges such

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as poor performance and dominance on large projects by foreign firms, (NCC, 2018). The NCC (2018) report and Muleya et al, (2022) reveal that 90 % of the Zambian contractors share 15% of the total contract values while the 10% foreigner contractors take up the 85% of the market share in terms of contract value. Literature from (Muleya et al, 2022; Chen Orr, 2009; Centre for Chinese Studies at Stellenbosch University, 2006; Osabutey et al. (2014)), reveal that financial capacity, experience, technical capacity, negative work attitude and access to modern equipment are some of the mayor advantages that favour foreign contractors in the award of large and complex projects such as highways, bridges and large commercial units. These statistics strongly suggests that despite governments investment in the infrastructure sector, few local contractors have benefited from the initiative in terms contractor growth financially and technically. Further, majority of these local contractor population lie between grades 4 to 6 which are at the tail end of the registration scale. Ghaleb et al., (2022) observed that construction projects have become dynamic in nature due to their increasing complexity and uncertainty. The increasing magnitude, complexities and risks associated with major construction projects have brought organizations together with diverse strengths, weaknesses and specialized experience to form Joint Ventures (JV) with the aim of collectively bidding and executing projects (Adnan, 2008; Adnan et al, 2012). According to the Road Development Agency (RDA) website, in 2012 government through the RDA introduced the 20% sub contracting practice. The initiative was designed to reserve 20% of the roads works for indigenous Zambia contractors. This policy statement was revised in 2018 but never provided tangible benefits because of the low percentage allocation to local contractors. Further, majority of these 20% works constituted road furniture, finishes and drainage resulting in reduced levels of skills transfer in areas of road sections.

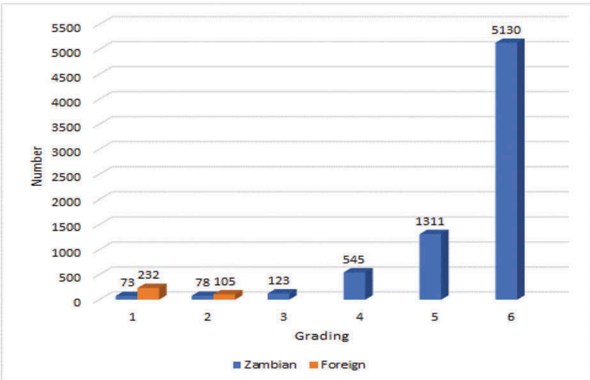

Figure 1. Grading of construction firms by number and ownership (NCC, 2018).

Figure 1 confirms that majority of the contractors are in the category of grades 4 to 6. Large scale contractors capable of undertaking large construction works are in grades 1 to 3 with foreign contractors being grade 1 and 2. Mwale (2014) and Kabaila 2014 stated existing financial strategies to help Small and Medium Companies (SMCs) in Zambia have been mostly found to be ineffective. The same findings further showed that about 62% of SMCs are still facing challenges in accessing finance, a situation which has hindered their development. Chan et al., (2022) showed that besides fulfilling financial objectives, contractors and consultants can enhance their performance and capacity through utilization of JV vehicles. In addition, Putter (2019) revealed that in developing countries like Zambia, JVs especially those with Multi-National Corporations (MNCs) can be highly instrumental in learning and technology absorption by local partners leading to contribution to building of local technological capabilities. 10 joint venture projects were identified through the NCC register, however, there was no information of the performance of these joint ventures. This study therefore set out to establish and evaluate the performance of joint ventures on construction projects in Zambia.

2 LITERATURE REVIEW

Tony & Michelle (2014) defines a JV as a construction collaboration of at least two construction organizations with a view to accomplishing mutually-agreed-upon objectives, wherein they share project risks, knowledge and resources. According to Chan et al (2022), JVs in the construction industry are usually launched on large and complex infrastructure projects. Construction joint venture (CJV) is the voluntary partnership of independent construction firms specifically created to undertake Architectural, Engineering, and Construction (AEC) projects. On the global construction market where competition is rapidly increasing, JVs have become a common form of business. According to Kamal (2010) JVs have become common because of the intricate and sophisticated nature of construction projects. Contractors of small and medium construction projects have adopted JVs because it can enhance their competitiveness by pulling construction resources (e.g., capital, equipment, skills and expertise) from the partners as well as allocating risk among the partners. Ozorhon, et al. (2010) revealed that for JVs to be successful and achieve their objectives, project and partner performance of a JV must be successful. With the increasingly changing dynamics in construction, formation of JVs is important especially to SMCs not only for enhancing resources for project execution but also for the growth of the local construction industry. Since the early 1990s, construction JVs have developed and are evolving rapidly in both international and local construction firms. Famakin et al. (2012) adds that organizations set up JVs to utilize partner resources due to the growing scale and complexity of construction projects, as well as technological advancements. The formation of JVs especially International Joint Venture (IJV) has been acknowledged as a critical factor for growth of firms in developing countries and for economic growth of the country (UNIDO, 2006). This is because IJVs give local firms an opportunity to acquire new skills and upgrade their technology. A Joint Venture project can be said to be a life cycle consisting of four major phases; (1) the beginning phase, (2) the formation phase, (3) the operation phase, and (4) the termination phase (Likhitruangsilp & Prasitsom, 2008). Each partner to the JV makes critical decisions at every phase that affects the JV management.

2.1 *Classification of joint ventures*

Ekpo (2019) states that JVs may be classified as Domestic Joint Venture (DJV) and or International Joint Venture (IJV). DJV is defined as the type of construction joint venture that is characterized with partners from a single country where as IJV is a type of construction joint venture involving international partners only or local and international partners (Echor and Lohor, 2021). JV parties can be individuals, partnerships or corporations that continue to operate independently from each other except for activities related to the JV. It differs from other alliances like mergers in the sense that there is no transfer of ownership in JVs. This gives them an edge as a strategic alternative tool in global competition.

2.2 *Types of joint ventures*

Although JVs are said to be partnerships in the actual sense, they can take up any legal structure. JVs can easily be classified by considering the arrangement of the alliance in terms of shares, allocation of profits/loss and allocation of work. Kale, et al. (2013) identifies the following main types of JVs. *Integrated Joint Venture* represents two or more partners to the JV that combine resources and employees resulting in sharing of profits and losses according to their percentage of interest. N*on-Integrated Joint Venture is a* restricted non-partnership joint venture where every party is assigned a range of work and is responsible for the profit, loss, and resources related to that work. Every party to the JV is assigned a portion of work and is responsible for their own profits and losses (Rwelamila & Mkandawire, 2015). *Equity Joint Venture* is another type of JV where there is participation of at least two partners in the creation of a new corporate entity in which each partner claims a given portion of the share capital. Further, *Contractual Joint Venture* is a contractual JV where there is no equity participation between the partners and their relations. It is formed when an agreement to co-operate with another company in a limited and specific way is formed.

2.3 *Motivation for forming construction joint ventures*

There are many reasons that drive firms to form JVs and some of these reasons forwarded are as follows: Knowledge sharing: Martin & Emptage, 2019; Technology transfer, Friedel, 2007; Competitive strategy: Ozorhon, (2007); Sharing of commercial risks: Minja, et al., 2012; Entry to new markets, (Ozorhon, 2007; New and combined expertise (Dong et al, 2019). Drawbacks of joint ventures and performance factors. Like any other partnership, joint ventures are not without challenges and drawback. Some of the JV drawbacks include no exit mechanism, lack of trust, unclear partner roles, unfairly written agreement, lack of mutual understanding, lack of commitment, Poor communication, lack of partner experience, (Adnan & Morledge, 2003; Beamish & Berdrow, 2003; Lambe, et al, 2011; Omar & Fayek, 2014; Adnan, et al., 2018; Chen, et al., 2020)

Joint ventures must take drawbacks as risks and draw up mitigation measures. Performance of joint ventures depends on many factors which can result in drawbacks in not well executed. Performance can be defined as a complex series of actions that integrate skills and knowledge to produce a valuable result (Romero, et al., 2014). Factors of performance in joint ventures include cost and time performance (Egwunatum, 2017), quality performance, clent satifaction and health and safety. Others include project uncertainities (Alexander, 2020), change orders and variations, (Khahro, et al., 2017) and payment delays (Gebrehiwet & Luo, 2017)

3 RESEARCH METHODOLOGY

Literature was reviewed to identify research parameters for the field survey that was to be conducted to find out whether works shared by each JV partner were completed and whether the projects were delivered on time, to the expected quality and within the given budget. The areas that were considered for the collection of data were Lusaka and Copperbelt provinces. This is because the target population comprising clients, statutory bodies, consultants and contractors involved in the selected JV projects are based in the two provinces. Government ministries and public organisations were selected as clients for this study. Contractors, consultants and regulatory bodies were targeted for data collection having been key stakeholders in the selected JV projects. Purposive sampling was predominantly used because JV projects had to be specifically identified and selected to meet the overall aim and objectives of the study (Andrade, 2021). Snowball sampling was used for consultants because contractors engaged in the selected JV projects were identified and thereafter asked to identify consultants that were attached to the respective projects (Parker et al., 2019). The sample constituted all the 10 construction Joint Venture projects registered by National Council for Construction (NCC) at the time of conducting the research. The 10 construction JV sample constituted 14 contractors, 3 clients, 4 consultants and 1 statutory body bringing the total number of respondents to 22. Questionnaires were used to collect data due to the nature of the study that many parameters that would be easy to analysis quantitatively. Microsoft Excel was used to process data and generate relative importance index in order to rank the parameters in their order of importance. Further means were generated and used for some parameters

4 RESULTS AND DISCUSSION

The population for JV projects was classified as unknown due to lack of reliable data bases particularly in the private sector and as a result, joint ventures projects in the private sector were not captured for the study. An average rate of 76% was recorded from the target sample as seen in Table 1. Non availability of information resulted in generally smaller sample. All the JVs used in this study were identified through the regulator, which is the NCC.

Table 1. Respondents information.

Respondents	Sample size	Questionnaries distributed	Questionnaries received	Response rate (%)
Contractors	14	13	10	77
Clients	3	3	2	66.67
Consultants	4	4	3	75
NCC	1	1	1	100
Total	22	21	16	76

4.1 *Nature and type of JVs*

Figure 2 and Figure 3 shows types of JVs from the 10 that were identified. Results indicate that there more local JVs than international JVs. In terms of the type of JVs, the study established from the sample that there were more integrated and non-integrated JVs. These results reveal that there is activity between local JVs and between international JVs which a good sign of JV existence and their balanced growth in the Zambian construction industry. Despite being mandatory to register JVs with NCC, the organization does not capture all the JVs in Zambia and this makes it difficult to assess and evaluate all the JV projects in the country. These results provide an acceptable representation of types and nature of JVs found in literature as stated by Kale, et al. (2013) and Rwelamila and Mkandawire (2015).

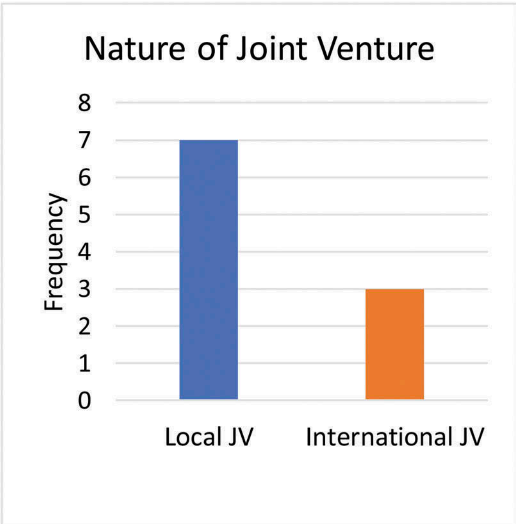

Figure 2. Nature of joint venture.

4.2 *Motivation for forming JVs in Zambia*

Figure 4 shows that many of the factors identified in literature review were the reasons for motivation of JV formation in Zambia with entry into new market and increasing financial resources recording a mean of above 4. This is because majority of Zambian contractors are SMCs that are faced with many challenges such as lack of access to finance and stiff competition for work. On the effectiveness of existing financial strategies to help SMCs in Zambia,

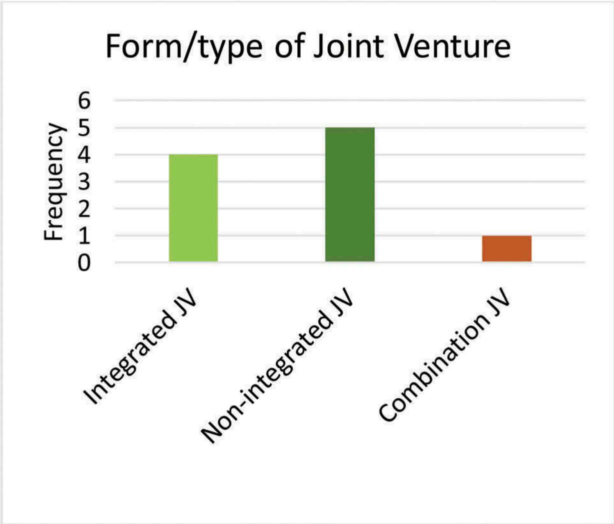

Figure 3. Form/type of joint venture.

Mwale (2014) found that most of these strategies are ineffective and that 62% of SMCs are still facing challenges in accessing finance a situation which has hindered their development. It is however worrying that taping into new technology and knowledge was ranked least which could imply low appetite for new technology and/or new knowledge or simply lack of exposure. Ideally, this should be one of the leading motivational reasons for JV formation particularly where an international contractor or stakeholder is available.

4.3 *Project related factors*

Table 2 revealed that major project related factors affecting project performance on construction JVs on Zambian projects in the study were; delay in payment by clients triggering suspension of works and lack of cooperation as second raked factors. Work stoppage has in the recent past become a major setback even on non-JV projects. Labour shortage and poor materials were the significant factors from the study.

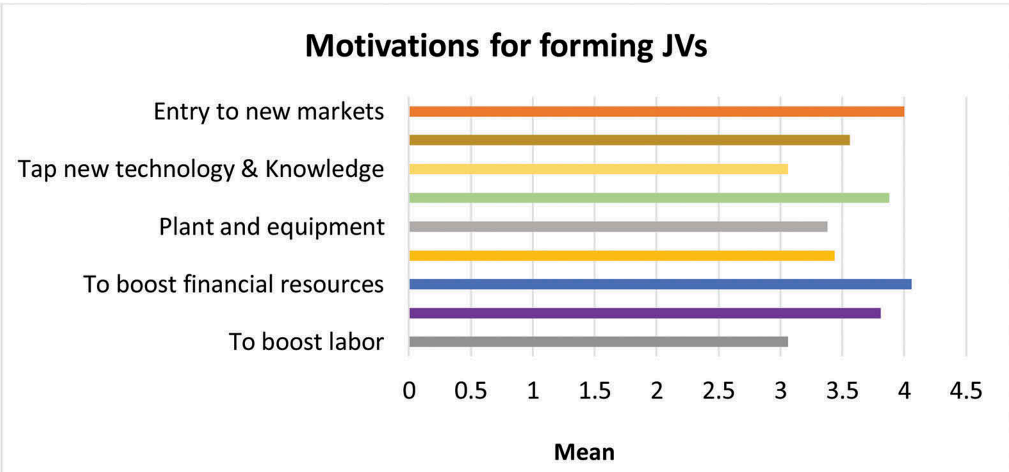

Figure 4. Motivation for JV formation.

Table 2. Project related factors.

No	Factor	RII	Rank
1	Payment delays by client	0.875	1
2	Suspension of works	0.725	2
3	Unrealistic project duration	0.625	3
4	Inadequate plant & equipment	0.575	4
5	Incompetent contractors	0.563	5
6	Incompetent consultants	0.563	5
7	Poor project planning	0.538	6
8	Change order/variations	0.5	7
9	Poor quality of materials	0.475	8
10	Labour shortage	0.45	9

4.4 *Parameter related factors*

Table 3 shows that lack of commitment, inadequate partner skills and lack of cooperation proved to be the most significant factors contributing to poor partner related challenges on JVs in Zambia. The objectives or goals of a JV are mutual and therefore, without cooperation among partners, it would be difficult for partners to share information and resources which are essential for successful delivery of projects through JVs. These factors border on risk and quality management which local contractors must improve in order to raise the performance of JVs in Zambia

Table 3. Parameter related factors.

No	Factor	RII	Rank
1	Lack of commitment	0.725	1
2	Inadequate partner skills	0.725	1
3	Poor communication	0.725	1
4	Lack of cooperation	0.725	1
5	Lack of trust	0.713	2
6	Unfair JV agreement	0.638	3
1	Poor work quality	0.625	4
2	Mismanagement of construction resources	0.6	5

4.5 *Success outcomes on construction JVs in Zambia*

Figure 5 shows that reduction occupational accidents,skills transfer, technology transfer and conformance to standards were some of the successes recorded during the construction joint venture projects. Skills and technology transfer included usage of equipment and project/contract documentation. Evidence from Figure 5 shows that despite facing the draw backs and challenges, successes were still recorded on the JV projects. One interesting result is that despite new knowledge and technology transfer having been the least ranked as reason for motivation, the result in this area is impressive.

4.6 *Performance of joint ventures in Zambia*

Results clearly indicate that the status of construction JV projects in Zambia on motivation for JVs, type and nature of JVs, project and success parameters, challenges and successes are not different from what is contains in literature as discussed in the literature review section. The study however provides details of areas of improvement to make JVs perform better in the Zambian construction presented in sections 4.1 to 4.4. In addition to the areas of improvement under the discussion section, one critical area that will promote better performance of

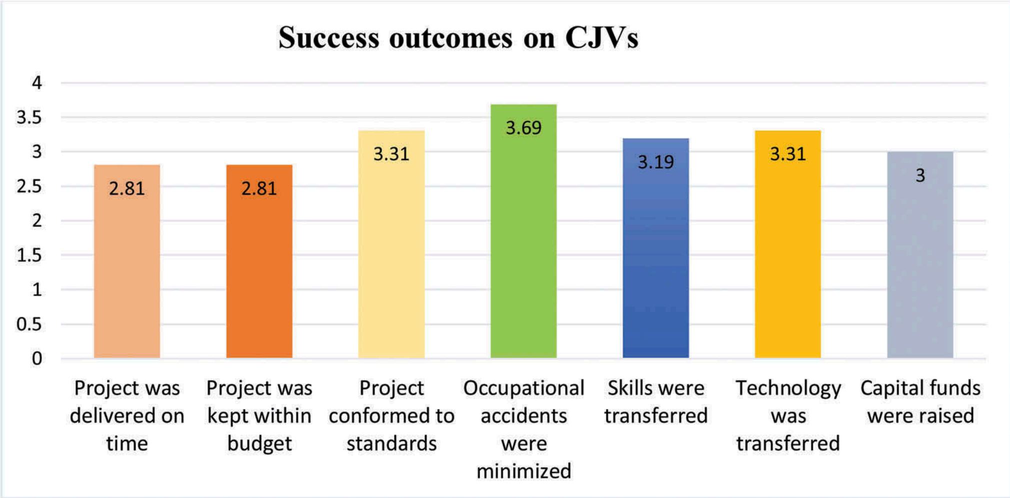

Figure 5. Success outcomes of construction joint ventures.

JVs in Zambia is the creation of a deliberate platform and mandatory policy preferable embedded in the signed contract to transfer skills and knowledge to local firms through JVs because that is currently missing. These results are consistent with (Ozorhon, 2007; Romero, et al., 2014 and Egwunatum, 2017)

5 CONCLUSION

Results from the study indicate that different types and nature of JV projects exist in Zambia with public sector clients involved, at least for this study. There is evidence of successes and challenges as revealed in the findings. Results suggest that local contractors in the SME category needs more skills and technical knowledge transfer. The areas of weakness and failure such as delayed payments, lack of commitment, inadequate skills and lack of trust cannot be ignored. These are fundamental elements of successful JVs. Unless these areas are addressed, the construction industry is less likely to grow in terms of JVs. One limitation identified is that JV projects from the private sector were not captured due to non-availability of information. The study also concluded that project, parameter and motivational factors discussed in literature review also affect JV projects in Zambia as seen from the research results section. The study recommends that JVs between local companies and international companies be promoted to allow for skills, new knowledge and technology transfer driven however, a well-designed and deliberate platform is currently missing. The results further suggests that clients must be consistent with payments to contractors to avoid suspension and flow of work which triggers other related challenges such as lack trust and commitment among JV stakeholders internally and externally. The implications revealed in this study strongly indicate that there will be less benefits drawn from JVS in Zambia if factors identified in this study are not given the attention that they deserve.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Improving the bankability of PPP-financed railway infrastructure projects in Southern Africa: Establishing critical success factors

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ABSTRACT: Railways offer cost-effective platforms for cross-border trade. In response, successive governments have developed innovative financing mechanisms. Although PPPs are considered a funding mechanism, they have been criticized. Many studies have examined PPP-financed rail infrastructure in developing countries (Africa), but little attention has been paid to bankability. Through the identification of critical success factors, this study contributes to bridging the knowledge-practice gap for railway infrastructure projects. A case study design strategy was adopted focusing on projects delivered within Southern Africa. Data were obtained from a purposively selected panel of respondents (n=13) via an interview, and a Delphi questionnaire was administered to the panel over three iterations. The data were analyzed using thematic analysis and descriptive statistics respectively. In the study, a number of critical success factors were identified that can enhance railway infrastructure project bankability. These findings will be used in the future to improve the bankability of these projects.

Keywords: traffic-determination, transport, investment, investability, bankability

1 INTRODUCTION

In both developed and developing countries, trillions of dollars are required to build infrastructure for economic growth. However, bankability in African economies is a challenge (Fioravanti et al., 2019). Africa's ability to fill its greenfield infrastructure gaps depends on a delicate balancing act between development banking and institutional investment over the long term (Fioravanti et al., 2019). Despite this, the government has been restricted in its efforts to reach this target on its own due to among others the austerity measures and financial constraints sustained by global financial imbalances (Bonizzi et al., 2020). The lack of bankability challenges and the uncertainty surrounding PPP-financed projects limit the institutional investors from tapping into trillions of dollars of non-listed infrastructure investments. In addition to stable cash flows with hedges against inflation attributes, infrastructure assets have a low correlation to both macroeconomic conditions and other assets, which would have guaranteed the participation of private investors in the infrastructure market and led to the rapid disappearance of the infrastructure gap (Oberholzer et al., 2018). With an emphasis on Southern Africa, railway transport infrastructure faces many challenges but uniquely is the investability and bankability of PPP-financed projects. This study focuses on establishing critical success factors for PPP-financed railway infrastructure projects in Southern Africa to

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improve their bankability. By improving the quality of projects, reducing and mitigating risks, and leveraging private financing bankability of PPP-financed railway infrastructure projects can be enhanced. It has been argued in several studies that foreign financiers interested in African PPPs must consider not only the commercial risks of the projects but also the risks related to the country (Adedayo and Oyedele, 2019). There is, however, a need to explore critical success/encumbrance factors of bankability in Southern Africa. PPP financing can thus be seen as an ideal method for funding infrastructure deficiencies. On the other hand, some have claimed that PPPs are an idealized form of privatized Keynesianism. The key objective of the study is to establish critical success factors with the aim of improving the bankability of PPP-financed railway infrastructure projects in Southern Africa. The data instruments employed for this task was semi-structured interviews, and the Delphi technique. The remainder of the study is organized as follows. Section 2 critically review the literature through the theoretical foundations, Section 3 critically evaluates methodological approaches, Section 4 presentation and discussion of findings, and Section 5 conclusions.

2 LITERATURE REVIEW

Most African countries are planning to build new railways or refurbish old colonial railways which will cost around \$4 billion to \$8 billion (Emid, 2017). There are connectivity barriers and inefficiencies in the transport sector due to the constrained operations of Kenya's colonial railway system (Githaiga, 2021). Hindsight suggests the Sishen-Saldanha railway project was an undertaking of immense proportions in South Africa's history and it is the world's longest rail track for iron ore freight (Hendrich, 2021). In a country with abundant mineral resources, reliable and efficient access to the coast became essential for export purposes. The railway system is the backbone of most national economies for the transportation of minerals. This study focuses on Southern Africa, where financing/funding of these railway projects is a major challenge. Although there have been a number of project finance investments in emerging markets (EMs) already (Bhatia, 2019), financing infrastructures through PPPs has proven to be challenging for foreign lenders (Ameyaw and Chan, 2015). However, both bankers and public officials are often driven by a "transaction culture" which emphasizes the "bankability" of projects. The main challenge investors face is long-term "investability", which involves managing assets over the long term (Inderst, 2021). For a project to be considered sustainable, bankability must present guaranteed investability in the form of demonstrated cash flows. The financial model that underpins the bankability study of the project concerned needs to evaluate revenues and costs along a study horizon of (n = years). Taking all considerations into account, a project structure is "bankable" if lenders are willing to finance it. Lenders need to be convinced that a project company can service the debt for the project to be bankable. According to the suggested Finance Structures for PPP, operating cash flows would need to be sufficiently high to cover debt service plus a reasonable margin under a project finance structure. Consequently, investors must realize over time the potential for investment; the quality of being a profitable investment. Moreover, bankability varies and may involve wider macroeconomic factors, such as the economic and political stability of the project's host nation, an appropriate legal and regulatory framework, and a smart financing structure, to name a few (Adedayo and Oyedele, 2019). Although multilateral and bilateral agencies play active roles as project financiers in Southern Africa, there is still a concern about bankability for PPP projects, so in many instances, obtaining a foreign loan by indigenous sponsors usually poses a sponsor risk (Adedayo and Oyedele, 2019). Moreover, political risk is generated when civil unrest, currency devaluation, leadership instability, and weak legal frameworks for PPPs are present (Adedayo & Oyedele, 2019). Expropriation and government repudiation of contracts severely restricted the growth of Africa's PPPs, with 80 percent of contracts attracting disputes and eventually being cancelled between 1990 and 2004 (Kayaga., 2008). When cancellations of PPP initiatives occur, they tend to dampen market confidence in government commitments. PPP arrangements require full compliance with the project's output specifications, performance contracts, and concession termination clauses (Adedayo & Oyedele, 2019).

As such, failure to comply with PPP regulations may cause concession-related risks given the weak PPP culture, institutional and regulatory frameworks in many Southern African economies. Due to the huge investment at stake in PPPs, contractual infractions and consequent statutory deductions may jeopardize foreign financiers' investments. Typically, these risks arise when PPPs violate domestic laws of host nations or when approval and permits are delayed or denied (Blumenfeld et al., 2019). Consequently, bankability is only achieved in PFI/PPP projects where proven and tested technology is applied from the beginning to the end, and this leads us to the development and control of standards, which are no longer under the control of most Southern African countries (Taglioni & Winkler, 2016). PFI/PPP loan applications can be assessed as bankable if independent technical consultants are available and other technical and related expertise is harnessed with effective governance to develop industry standards, making southern African countries less advantaged (Adedayo & Oyedele, 2019). However, the purview of this study only identifies factors that determine success in PPP-financed railway infrastructure projects in Southern Africa, thus increasing bankability.

3 RESEARCH METHODOLOGY

The establishment of critical success factors for improving the bankability of PPP-financed railway infrastructure projects in Southern Africa was carried out in phases involving semi-structured interviews and a Delphi questionnaire technique. Interviewees were selected based on their involvement in PPP finance projects but experts in construction, exposed to PPP finance projects but knowledgeable about finance, and involved and experts in both PPP finance and construction. Thirteen (13) experts were identified as interviewees. PPP financing specialists with extensive experience were hard to find, which led the described approach to be endorsed. The researcher included a larger group of participants with sufficient knowledge of finance structuring, but primarily associated with infrastructure projects. As illustrated in Tables 1 and 2, a brief overview of the respondent's background is given. The experts who participated in the interviews were enthusiastic about the study, so they readily offered to participate in the Delphi process.

Table 1. Exposure of the participants in the industry.

Exposure of the participants in the industry	CODE	No. of participants
Engineering and Infrastructure Association	Respondent 1	2
Commercial Bank	Respondent 2	2
EPC Logistics Transportation	Respondent 3	2
Rail International Group	Respondent 4	2
Government Treasury	Respondent 5	3
Original Equipment Manufacturer	Respondent 6	2

Due to the multidisciplinary nature of the infrastructure, participants were able to seamlessly switch between sections, except for those with pure engineering and finance backgrounds. As demonstrated in Table 2 their level of involvement in infrastructure development was further substantiated by their experience. Although most participants were from South Africa, their experiences in infrastructure development deployment reached all of Africa, including SADC or Southern Africa. South Africa is the most industrialized country in the SADC, so most Original Equipment Manufacturers (OEMs) are based in that country. In the Southern region of Africa, the most sophisticated commercial banks are located in South Africa. Construction and infrastructure companies with headquarters in South Africa are not exempt from this rule. It is South Africa that serves the Southern African region with EPCs and consulting engineering firms.

Table 2. Participants' experience in infrastructure development.

The period involved in Infrastructure Development	Response	Ratio
More than 20 years	10	77%
More than 10 years up to 20 years	3	23%
0 to 10 years	0	0%
TOTAL	13	100%

Specifically, the investigation focuses on improving the bankability of PPP-financed railway infrastructure projects in Southern Africa. Additionally, due to the paucity of expertise in PPP financing of the railway infrastructure, snowball sampling and chain referral sampling were allowed, both of which were non-probability sampling methods in which samples were randomly selected based on traits that proved difficult to identify (Rai, 2015). Data collected from different instruments were analyzed in different ways using the already stated semi-structured interviews and analyzed using thematic analysis while the Delphi utilized questionnaires to reach a consensus by the experts.

4 PRESENTATION AND DISCUSSION OF FINDINGS

The feedback was gathered from interviewees of experts, and their demographics are shown in (Tables 1 and 2). Their direct responses to improving the bankability of PPP-financed railway infrastructure projects in Southern Africa. A thematic analysis using Microsoft Word was used to generate themes for semi structured interviews, followed by Delphi interviews.

Project preparation was highlighted extensively and this was confirmed by Respondent 1 *"Rail is capital intensive therefore project preparation (PP) must take a long-range view that is financed through future cash flows"*. While Respondent 2 argued *"There is no shortage of finance for projects which are bankable, the problem lies with PP, the first problem is politician push unbankable projects for expedience"*. This makes a confusion on both funding and financing for bankability. Respondent 3 raised the concern on financing structure and the process for the consideration of local technology and he made his point by citing the case of Morocco from the supply countries "*The case of Morocco from the supply country "high speed rail network is built through the loans integrated with grant money provided by French government for the economic prospects of Morocco, however, the construction is built by French companies, the rolling stock is built and operated by Alstom"*. Respondent 1 continued emphasizing PP "*The impact of PP is impeded by many legal frameworks PFMA, the procurement processes need to be streamlined. Constructability that must be compatible with the design of the project vice versa. In most instances that is not happening where public sector is procuring"*. It was made clear that there are areas of concern demanding attention as Respondent 2 further explained *"The regulatory framework is premised on the incorrect foundation, it is unnecessarily complicated, for example we need to have sector focus PPP regulatory framework"*. The respondents all agreed that traffic in railways determine the cash flow as Respondent 4 explained *"Export lines are the money spinners for any rail operator but cash flows must be accurate as an investment is a long term, therefore you got to place the rail line for right reasons"*. However, liquidity was also highlighted by all respondents and Respondent 5 articulated *"Liquidity impacts PPP significantly, however, there is a lot of idiosyncrasies or call it peculiarities in the application of PPP. Therefore, traffic predictions that determine the cash flows must be accurate"*. What also came as prominent is the credit access by Southern African countries and Respondent 6 explained *"The OECD credit classification/CRA, the lowest risk is Botswana, State credit and CRA, Harmonization of the legal system is critical*". Respondent 6 further explained *"Inappropriate political pressure for projects to happen, insufficient traffic determination, unnecessarily government guarantees by Treasury, government implement reforms in an ad hoc manner"* All respondents highlighted the cross-border nature of railways and Respondent 2 describes as the heterogeneity of contracts *"Moving across borders is a challenge, you may have different power supplies, rules, insurances, and different gauges"*. As a result of this phase of data collection and analysis, a theme has been formed based on the responses of the experts, and a few of these responses have been directly cited.

Theme 1: Establishment of factors for improving bankability of PPP financed railway infrastructure in Southern Africa from the semi-structured interviews. In the literature, twenty-one factors were identified, and in semi-structured interviews with experts, thirteen factors for improving bankability were derived. These factors were then taken to the Delphi and a theme was developed.

Theme 2: Determining critical success factors for improving bankability of PPP-financed railway infrastructure in Southern Africa. The Delphi technique involves multiple iterations to reach a consensus on differing opinions about a given topic (2nd theme).(Henning & Jordaan, 2016).

Level of Consensus

A range of methods is available for determining the level of agreement between different opinions, the coefficient of variation, the interquartile range, and the standard deviation (SD) of the data.(Avella, 2016). For the purposes of this study, the level of consensus indicated by (Globbelaar, 2006) was used as a guideline on which to base decisions of consensus in terms of SD, as shown in Table 3.

Table 3. Decision criteria used in determining level of consensus achieved according to standard deviation.

Coefficient of variation	Decision Rule
$0 \leq x \leq 1$	High level
$1.01 < x \leq 1.49$	Reasonable/fair level
$1.5 \leq x \leq 2$	Low level
$2 \leq x$	No consensus

Source: (Globbelaar, 2006)

Data Used

The Delphi technique was conducted based on feedback from the interviews, and the critical success factors were derived from Theme 2, which was built from expert insights. The questionnaires were sent to the aforementioned experts via electronic mail. The resulting feedback was sent back to the researcher. In the next round of analysis, the attributes of the factors in semi-structured interviews and in the Delphi technique questionnaires have been evaluated against the literature. Theme 2 was developed as a result, and it aims to determine the critical success factors for improving the bankability of PPP-financed railway infrastructure based on the Delphi method. Through this process, critical success factors for PPP-financed railway infrastructure projects were identified as shown in Table 4.

Rounds Iterations

In the third round, respondents had the option of confirming what was agreed upon in the second round or adjusting their original answers. Feedback was provided using average scores and the mode for each of the factors and statements in theme 1 and theme 2. Midpoints of the responses were categorized by the median score. Therefore, the results in Table 4 indicate that satisfactory consensus levels were reached after the third round. In the third round, all factors that were considered reasonable in the second round were changed to points of high consensus.

Table 4. Summary of results for the Delphi third round, illustrating the average, standard deviation, mode, median, and consensus level for factors as mentioned by respondents.

Factor	Average	SD	Mode	Median	Consensus Level
Theme 2					
Project Preparation	4.44	0.73	5.00	5.00	High
PPP Regulation Framework	4.11	0.60	4.00	4.00	High
Credit ratings scores	3.44	0.53	3.00	4.00	High
Domestic technology standards	3.67	0.5	4.00	4.00	High
Design of projects	3.67	0.5	4.00	4.00	High
Homogeneity of contracts	2.89	0.78	3.00	3.00	High
Traffic determination	3.78	0.67	4.00	4.00	High
Cash flow projections	3.78	0.67	4.00	4.00	High

5 DISCUSSIONS OF SEMI-STRUCTURED INTERVIEWS AND DELPHI TECHNIQUE

The semi-structured interviews were conducted according to the interview guide's "interview protocol," which involves a verbal exchange in which the interviewer seeks information from the interviewee (Carter & Alvarado, 2019). A Delphi questionnaire was developed based on factors derived from semi-structured interviews. Despite the fact that the factors had already been listed, the panelists discussed them openly and added a few more recommendations. The direct rating according to the Likert scale only began in round two, though the process was still far from congruent. There were only eight factors rated as factors improving the bankability of PPP-financed railway infrastructure projects in Southern Africa, thus as factors critical to success. Project preparation, which has averaged 4.44 out of 5 and has a median and mode of 5, was identified as the most important factor. In addition to having an average score of 4.11, PPP regulation frameworks have a median score of 4 and a mode score of 4, indicating a significant level of criticality. Traffic determination, cash flow projections, design of projects, and domestic technology standards with average scores of 3.78, 3.78, and 3.67, 3.67 respectively. The modes and medians for these factors were all equal with a score of 4. In addition, Southern African credit ratings, with an average score of 3.44 and an equal mode and median of 3, were found to be influential and critical. In order for the railway infrastructure projects to be funded and financed, the credit rating of the Southern African countries was considered fundamental. The homogeneity of contracts also scored an average of 2.89 with the same mode and median.

6 CONCLUSIONS AND IMPLICATIONS

The main objective of the research was to explore the critical success factors for improving bankability of PPP-financed railway infrastructure in Southern Africa. Semi-structure interviewees and the Delphi study was conducted to determine these critical factors. In total, 8 different factors were identified as being critical for improving bankability of PPP-financed railway infrastructure in Southern Africa. These factors are project preparation, PPP regulation framework, credit rating scores, domestic technology standard, design of projects, homogeneity of contracts, traffic determination, and cash flow projections. The results show that there is consensus on the factors that are considered as critical success for improving bankability of PPP-finance railway infrastructure projects. Specifically, the study focuses on railway operators and financial institutions that are at the forefront of infrastructure investment. In addition, this study is applicable to the institutionalization of project preparation success, which will require a reevaluation of contract standards to ensure that they are in line with effective regulation. Through a PPP regulation between principals (governments) and agents (railroad operators), the study can be used as a blueprint for power separation. Moreover, the study can enhance governance within the process of infrastructure investment to ensure smooth bankability of railway infrastructure in Southern Africa.

7 LIMITATIONS OF THE STUDY

Africa's infrastructure problems are similar across the continent and adversely impact all its economies. The study only focused solely on the infrastructure landscape in Southern Africa. Although the study focused on railways within the transport class of assets, infrastructure encompasses a broad discipline with various categories inherently having similar attributes. To complete the study under the time limit, the study sample was limited to appropriate the approach applied, thus there was no use of statistical methods.

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Infrastructure: Shock events, procurement, project management, health & safety

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

An analysis of the impact of the COVID-19 pandemic on construction projects

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ABSTRACT: The COVID-19 pandemic has impacted all the economies to an unprecedented extent and India is no exception. The construction industry, largely characterized by labor-intensive work, has been impacted severely – with productivity losses, delays, cost overruns. The present paper has taken up the case of a real estate project in India for study and the impact of the pandemic on project execution has been analyzed and presented. The project witnessed labour attrition, an increase in the prices for some materials viz. cement, steel, bricks, diesel etc. by 35% to 50%, delays in the project, reduced demand for the project etc. A questionnaire survey has also been conducted to examine the extent of the impact of COVID-19 on labour's earnings and the impact. The paper also discusses the mitigation measures adopted by the builder of the project to reduce the impact on the case study project and recover from the impact.

1 INTRODUCTION

The COVID-19 pandemic has resulted in unprecedented disruption to the world economy and has impacted all the economies and various industrial sectors. The International Monetary Fund reported that the world economy shrunk by 3.5% in 2020 (International Monetary Fund, 2021). During the pandemic period in 2020 & 2021, there was a huge loss of employment with several businesses completely winding up their business. It is estimated that the pandemic resulted in 114 million job losses globally, with about an 8.3% reduction in labour income, translating to an impact of $3.7 trillion (ILO, 2021a).

Construction projects act as the essential link for infrastructure development (Prasad *et al.*, 2019). Before the pandemic, the construction industry globally employed nearly 7% of the workforce (OECD, 2016) and accounted for nearly 13% of the Global GDP(ILO, 2021b). The COVID-19 pandemic which struck in March 2020, has impacted all the economies and its impact has been significant on the construction sector (Prasad and Bhat, 2022). The pandemic

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has disrupted all major construction projects unlike other sectors primarily owing to the fact that the industry strongly relies on migrant labour, and engages predominantly unskilled labours with very low earnings (OECD, 2016).

The Indian construction industry was witnessing tremendous momentum and was set to become globally, the third-largest construction market (Oxford Economics, 2021). Indian Construction Industry comprises nearly 200 major organizations, 12000 government registered class A contractors and employs nearly 50 million workers (Biswas *et al.*, 2021). By nature, the construction industry is prone to issues of delays, cost overruns, disputes and litigation (Padala *et al.*, 2020) and the pandemic worsened this case for India. The Indian construction industry falls within the group of these economies that employs 74% of the workforce and contributes to 23% of the global construction output (ILO, 2001). The pandemic causes severe stagnation of the projects with prolonged lockdowns and this paucity cost the industry £ 3 Billion every day (Biswas *et al.*, 2021; Prasad and Bhat, 2022). The impact of the COVID-19 on the Indian construction industry is widespread with an effect on nearly 250 allied sectors. Nearly 20,000 projects close to Indian National Rupees 60 Trillion (Rai and Sharma, 2021) are under implementation in India and most of them are expected to have a time impact of a minimum of 3 months and about 4% to 5% of the total project cost (KPMG, 2020a). The prolonged lockdown of 40 days from March to May 2020 resulted in the migration of nearly 0.6 million labour walking to their hometowns/natives with nearly 30% never returning to work (Rani *et al.*, 2022).

The slowdown of the industry and the projects had wide-ranging impacts pushing the industry by at least five years (*Business Standard*, 2020) – due to the reduced demands and sales there have been downsizing by organizations. The construction industry is characterized by the physical interactions and the pandemic posed a problem of remote working, thus lack of continuous interaction with the project team and seniors, leading to a decreased morale and increased workplace absenteeism (Deloitte, 2022), supply chain disruptions (Golan *et al.*, 2020), scarcity of labour for the execution of project activities (KPMG, 2020b). These have resulted in a foreseen increase of the cost of skilled labour by almost 25% and the project implementation costs by almost 5% (KPMG, 2020b). The present study intends to describe the impact of the COVID-19 pandemic on a case project in India and also on the industry in general.

2 LITERATURE REVIEW

The COVID-19 pandemic has impacted all of the industrial sectors including the construction sector. Since the onset of the pandemic, the employment opportunities have reduced, partially due to the work disruptions that arose due to the various measures initiated to stop the spread of virus (Pamidimukkala and Kermanshachi, 2021). Research studies have been conducted investigating the impact of COVID-19 on the construction industry/projects and this section summarizes the approach and findings of few of the studies.

Prasad and Bhat (2022) conducted a case-based study on one of the largest infrastructure projects in India. This study detailed the difficulties of maintaining the labour deployment, activity production cycles, social distancing norms, difficulties with material availability and the cost impact on the project and summarized the mitigation measures adopted by the company to overcome the difficulties.

Biswas *et al.* (2021) in their study summarized the impact of the COVI-19 on the construction industry across the world. The study analyzed the impact of slowdown on the GDP, issues with supply chain management, financial constraints, contractual implications and also suggested possible remedial measures to deal with the problems.

Bou Hatoum *et al.* (2021) analyzed the concerns of the construction workforce in the United States. This study adopted a qualitative analysis and analysed the complaints of the workers, trends and also the best practices across 11 major themes. The concerns of the employees ranged across many issues such as no enforcement of social distancing at sites, COVID-19 positive workers continued work, non-availability of PPE, non-availability of sanitization facilities etc.

Agyekum *et al.* (2022) conducted a study on the impact of COVID-19 on Ghanian construction companies. The authors conducted a semi structured interviews and thematic analysis was conducted with the help of NVIVO software. The study found a reduction in the work rate, payment delays and material cost escalation as the major impacts of the pandemic.

3 RESEARCH METHODOLOGY

The present study has adopted a case study approach to achieve the objectives of the paper. The case-based approach allows in depth exploration of complex issues (Crowe *et al.* 2011). The case study approach allows the researcher to exploit a larger problem and narrow the problem to manageable research questions (Heale, 2018). The authors selected a real estate project and analysed all the impacts and challenges of COVI-19 on the project and also the various possible steps taken up by the construction company to minimize the impacts.

4 CASE STUDY

The case organization, referred to in this report as ‘Mangalmurti Constructions’ is a major construction organization which is located in Nashik. It has been in existence for nearly 25 years and has built many landmarks in the city of Nashik. Presently the firm is working on many commercial and residential buildings and The Covid-19 pandemic had a huge influence on it, as it had on all other building firms in India. With significantly slowed physical and financial development, projects experienced significant delays and cost increases, as well as excessive labour turnover and a severe lack of working capital. The company has managed to turn over Indian National Rupees 6 crore in the fiscal year 2020-2021 compared to the respective previous year of Indian National Rupees 8 crore has shown a drop of 25 % due to the distressed, noncontinuous delivery of project material and labour. The next sections of

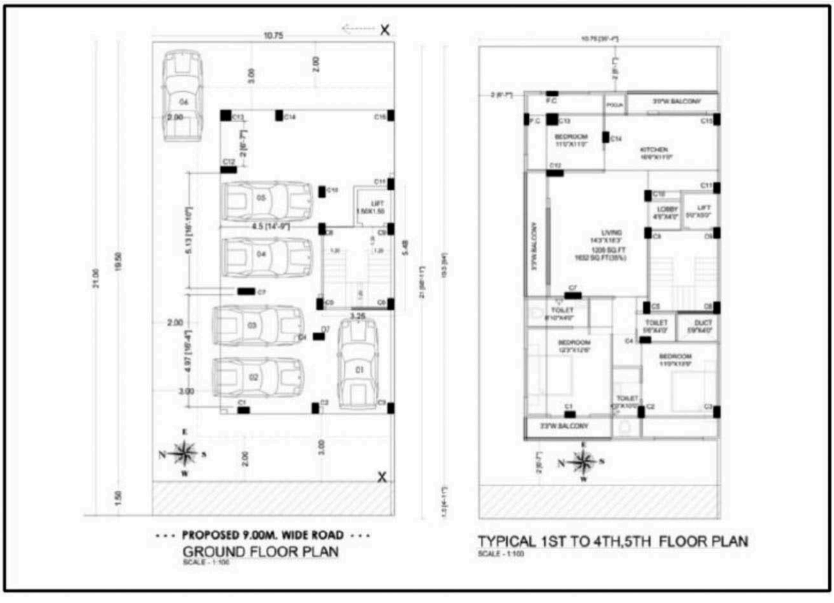

Figure 1. The schematic layout of the project.

this report focus on one of the organization's projects to show the organization's path through the pandemic, a (Ground floor+ 5 superstructure floors) residential buildings with 3 Phases comprising of 3 identical buildings each one similar to each other. The schematic layout of the project is shown in Figure 1.

'Morya Phase 1' is one of the '5 storey' (Ground floor +5 superstructure floors) buildings which started in February 2020 and was meant to complete its work within a year but due to extensive Covid-19 cases, the government of India decided to impose a lockdown and thus the activities on the site had to be stopped. As the work on the site was already in its preliminary stages and the company had already started paying wages to the employed workers so they had no other option but to continue paying the workers with a reduced salary. During that time the company ordered a large quantity of steel, cement and other materials, but as people were stuck in their houses, due to lack of attention, the materials such as cement came in contact with moisture, deemed useless. Hence the company incurred severe losses due to the wastage of construction materials.

4.1 *Challenges faced*

Labour Issues

The district has a total area of 15,530 sq. km. According to the 2011 census, Nashik district has a population of making it the 11th most populous India and the third most populated in Maharashtra, trailing only Mumbai and Pune. The population density of the district is 393 people per square kilometer. The amount of slum dweller families in the city is around 55,520. The city became an active centre of the pandemic and suffered the worst impacts. Figures 2 & 3 show the rise of Covid cases in Nashik from March 2020 to March 2022. By the end of March 2022, 0.27 million confirmed COVID-19 cases were registered.

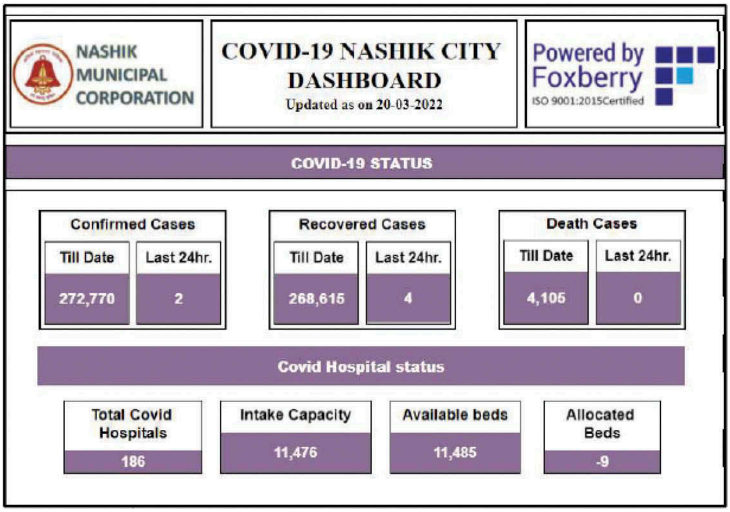

Figure 2. Nashik district COVID-19 dashboard.

In such a pandemic situation, workers and labourers all over India had to face a lot of challenges. The lockdown affected directly the salary of the workers (Jha and Kumar, 2020). Labourers were unable to work during the lockdown, therefore they began to leave the project sites to return to their native places (Jha, 2021) thus the number of employees drastically reduced, as shown in the first drop in Figure 4. Due to the complete lockdown from March to May 2020, the workforce was zero, and from May to August 2020, it varied at low levels, with new labour groups entering the project as previous groups left. The project team failed to find

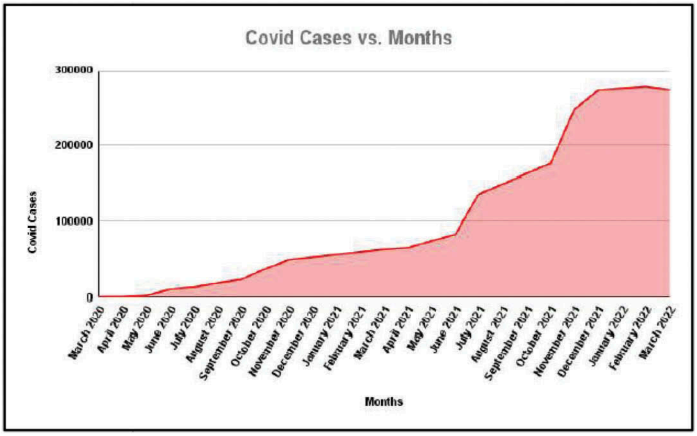

Figure 3. The cumulative trend of COVID-19 infections in the Nashik district.

individuals with sufficient skill levels and was forced to hire and train inexperienced workers as a result. While this aided in the resuming of work, productivity was lower than that in the pre-Covid era. The authors collected the data on the labour availability and deployment on the project site from the site human resources department and Figure 4 shows the trend of labour movement within the case study project from January 2020 to January 2022.

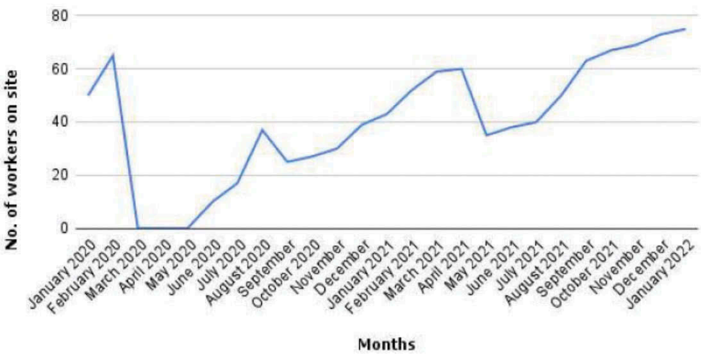

Figure 4. Labour availability trend on the case study project.

As may be seen from Figure 4, the full-time worker strength abruptly dropped from ~70 to zero in the month of March 2020 and it took nearly 1.5 years till August 2021, for the same strength to be regained. This caused enormous problems to the project's progress as well. The authors also conducted a questionnaire survey to assess the impact of this lockdown and as per this survey. 76 construction workers participated in this survey. 77% of the workers confirmed that they left for the natives/villages during the time of the pandemic. Figure 5 displays this response.

The workers were also asked about the impact of the COVID-19 pandemic on their earning potential. Naturally, during the lockdown, no work could be taken up and had to stop works and smaller companies couldn't afford to pay their salaries or could not pay full salaries. Many of the workers had to face salary cuts during this time. Figure 6 shows the response of the construction workers on this project. Nearly 82% of the workers faced a reduction in their salaries which also lead to further migration of the labourers even after partial work was allowed beyond August 2020.

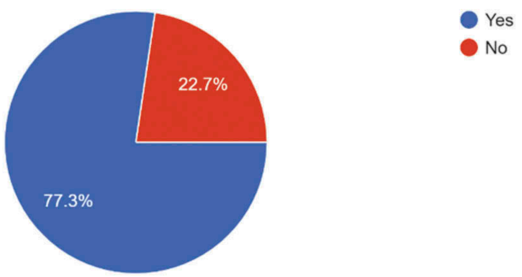

Figure 5. Percentage of labourers migrating to villages during the pandemic.

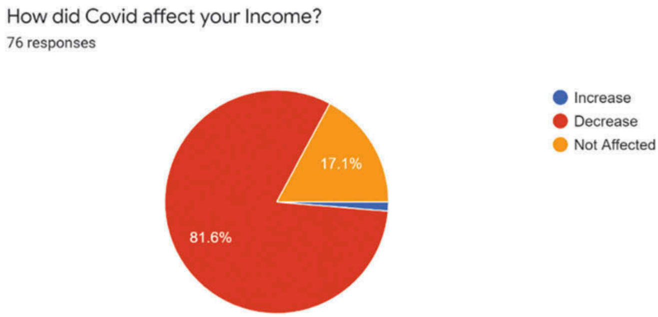

Figure 6. Impact of COVID-19 on the income of workers.

Material Price Increase

The pandemic also caused severe disruptions in the supply chain. The nationwide lockdown, along with the worker exodus, resulted in a drop in raw material manufacturing industrial production. The lead time and cost of construction materials increased as a result of this. In the 12 months following the commencement of the virus outbreak, the price (in Indian National Rupees) of all of the important construction materials in India jumped by 25-45%. The authors collected price data of the materials used on the project from the site procurement and stores department and the trend of the price rise from the obtained data are analyzed. The rise in trend of the key construction materials used on the project site is shown in Figures 7 to 10.

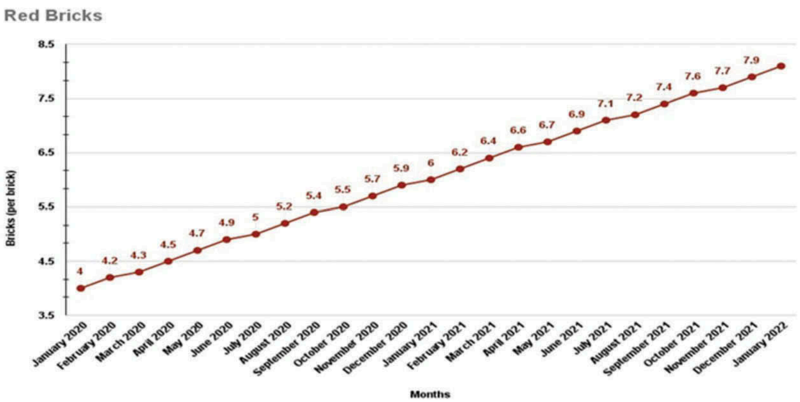

Figure 7. Increase in the price of red bricks used for the project.

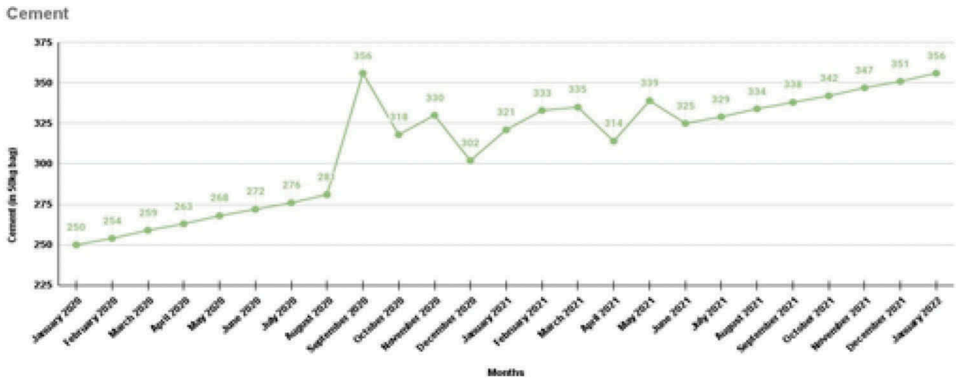

Figure 8. Increase in the price of cement used for the project.

As can be seen from Figures 7 & 8, the cost of red bricks has nearly doubled from Rs 4 per brick to Rs 8 per brick over the two years of the pandemic. Also, the price of cement has gone up from Rs. 250 per bag of 50 kgs to Rs 356 per bag, an increase of almost 1.5 times.

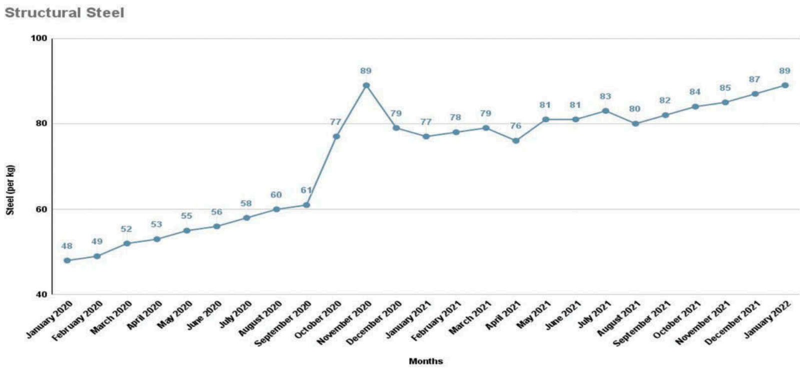

Figure 9. Increase in the price of structural steel procured for the project.

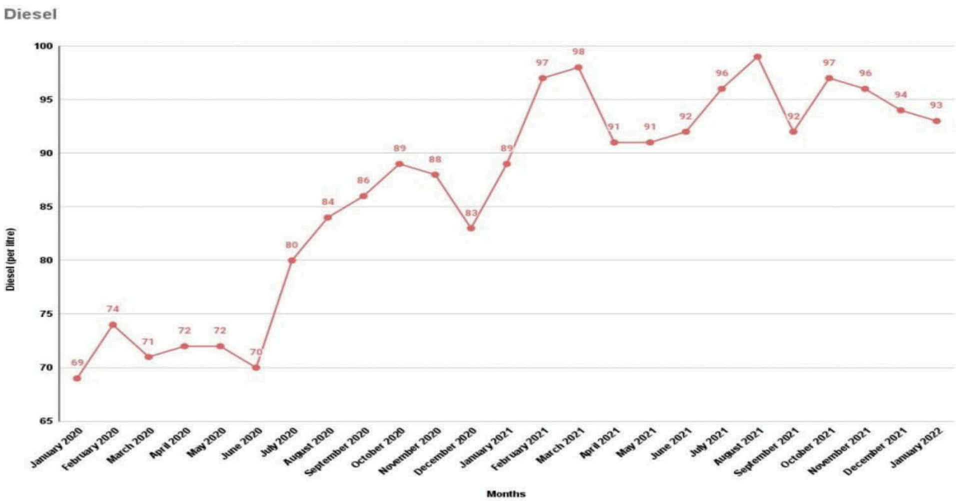

Figure 10. Increase in the price of diesel procured for the project.

Further, as can be seen from Figures 9 & 10, the cost of structural steel has nearly doubled from Rs 48 per kg to Rs 89 per kg over the two years of the pandemic. Also, the price of diesel has gone up from Rs. 69 per litre to Rs 93 per litre, an increase of almost 1.4 times.

With all of the prices of the major material inputs increasing by an extent of 40% to 50% on average, the builder taking up the project, could not sustain the cash flow for the project. In addition, the COVID-19 pandemic resulted in a drop in the productivity due to constraints in the execution, social distancing norms, and lesser labour availability on the project site. The estimated impact of the pandemic on productivity was in the range of 12.4% impact on the vertical construction productivity, with 50 minutes to 60 minutes lost per day of 8-hour work period. As per studies, a productivity impact of 10% could translate to a 100% impact on the profitability of vertical construction projects (McLin *et al.*, 2020).

Sluggish Demand for Property

With the onset of the pandemic, not just workers and labourers had to face problems but also common people suffered the same. The daily life of the common man was affected, due to a lack of access to continued disposable income. In addition, the remote work culture reduced the demand for commercial spaces as work from home has become a new normal today. This severely impacted the housing, commercial and mortgage markets (Balemi *et al.*, 2021). Further, the builder, in Nashik to accommodate for the productivity losses, increase in the completion times and escalated costs of various resources for the project, has increased the prices of the apartments by at least Rs 500 per sq. ft (*The Times of India*, 2022).

4.2 *Mitigation strategies adopted*

To tide over the difficult situation of the project, the builder adopted the following strategies –

1. Travel passes and allowances – To ensure the return of the labourers from the villages, the builder connected with the labour gang owners and provided the return tickets and passes from the place of work to the Nashik site.
2. Wage assurance – The workers engaged on the project site on an individual piece work basis could not earn to their potential due to reduced and restricted work hours and reduced productivities, the builder assured to compensate the labour for loss of daily wages by a fixed pay per day and incentives on achieving the physical progress targets.
3. Safe work practices – Builder provided the kits to labourers with sanitisers at work sites and labour camps, face masks and shields, on a free issue basis
4. Vaccination – The builder also arranged to conduct vaccine camps on the project site and insisted labourers and staff get vaccinated. With this approach, the builder was able to get 38% of the labour and staff fully vaccinated with two doses, while 11% of the labour were vaccinated with one dose. This further instilled confidence within the labour gang to continue the work. This can also be seen in the labour trend shown in Figure 4.

5 DISCUSSION & CONCLUSIONS

The COVID-19 pandemic has caused huge disruptions in the construction industry across the world. Projects have witnessed losses in productivity, scarcity in the availability of labour and all major construction materials, delays, escalations in the budgets etc. The present study has showcased the impact pandemic on a project in the city of Nashik in India covering all of these aspects in detail and also the wide-ranging impacts on the overall real estate industry in general. The project witnessed acute labour turnover during the lockdowns which affected the project progress and timelines. The severe restrictions on the movement of the people and resources during the lockdowns constrained the availability of key construction materials. This shortage also resulted in steep rise in the prices of key construction materials and therefore the overall cost of the project. The unprecedented situations required construction organizations to initiate strategies to overcome the impact and ensure sustainability of project works and progress. The paper also presented these mitigation strategies adopted by the case study organization to minimize the impact of the pandemic and to recover, and improve the progress, time and cost estimates.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)

Digital innovative technologies in construction health and safety: A systematic review of its benefits and future challenges

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ABSTRACT: While acknowledging the advancement of digital technologies in the construction industry, however, its application in the context of construction health and safety has not been fully integrated. This study unraveled the application of safety technologies by examining the benefits, and challenges facing its application. To achieve this aim, a structured literature review was conducted on the current research trends by reviewing selected articles from 2010 to 2022. The findings of the study attributed the benefits of safety technologies to; increased collaboration, improved productivity, reduced safety hazards, among others. The result also revealed that organisations' level of interest, resistance to change, unavailability of funds, unavailability of training capability, lack of assess to wireless broadband, among others. The findings from this study will be beneficial to researchers and industry practitioners on ways in which the advancement of safety technologies can improve the health and safety of construction workers.

Keywords: Digital Technologies, Health and Safety, Construction Industry, Digital Innovation, Safety Technology

1 INTRODUCTION

Health and Safety (H & S) refers to the wellbeing and safety of human from hazard (Chileshe and Dzisi, 2012). It consists of policies, processes, and programs that safeguard a person's wellbeing, health, and safety (Swallow and Zulu, 2019, Atkinson and Westall, 2010). Additionally, it seeks to safeguard the well-being of everyone who might be impacted by the working environment, including employees and the general public (Chileshe and Dzisi, 2012, Cheng et al., 2010). Thus, the construction sector has enormous challenges related to employee and public safety. Construction companies repeatedly fall short of putting into place H & S precautions on work sites (Nnaji et al., 2020, Okpala et al., 2020) and continue to battle with poor H & S implementation. It is vital that H & S in the construction sector receive greater attention than ever because the issue of health risks on building sites is a global problem (Malomane et al., 2022). As a result, numerous researchers are constantly looking for methods and procedures that could drastically enhance safety standards in the building sector. An analysis of the most current construction protection publications showed a significant trend toward the use of safety technologies for occupational safety (Yang et al., 2021, Malomane et al., 2022, Lingard et al., 2015, Ganah and John, 2015). Considering the fact that technologies may identify workplace dangers that are generally impractical for workers to avoid and can eliminate such dangers early in the project lifecycle, research on using technologies for ensuring safety has intensified (Rantsatsi et al., 2020, Muzafar, 2021, Getuli et al., 2017,

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Swallow and Zulu, 2019, Chileshe and Dzisi, 2012). Several studies have presented the various type of safety technologies and their uses in the construction industry. For instance, Nnaji et al. (2019) and Ahmed (2019) suggested the adoption of Virtual Reality (VR) to educate employees on H&S so that accidents can be avoided. Likewise, Malomane et al. (2022) opined that drones can be used in a variety of construction projects to carry out a number of activities, including inspecting the job, keeping an eye on workers ' safety, and tracking the movements of vehicles while scanning for dangers. On the other hand, Nnaji et al. (2019) suggested the use of smart sensor technologies and management to use real-time safety detection and warnings to avert potential risks to people and vehicles and report to centralized management systems. Additionally, the study by (Ikuabe et al., 2020) asserted that the level of awareness of digital technologies in construction is still low. In the same vein, Osunsanmi et al. (2019) observed that although RFID can assist in tracking the safety of construction personnel, its implementation has been hindered by both the high cost of procurement and poor standards of technical proficiency. Okpala et al. (2020) also revealed that there are only a few technologies used in the construction industry. Furthermore, Muzafar (2021) and Ganah and John (2015) mentioned that numerous safety solutions exist that can improve both work efficiency. Nevertheless, implementation of safety technology is quite poor in the construction sector, despite the status of H&S management. Given the increasing need to move towards sustainable construction practices, the clamour for safe work environment through sustainable construction practices, the clamor for a safe work environment through enhanced integration of technology in safety management is expected to increase. Therefore, to integrate safety technologies in the construction sector, it is necessary to look into the benefits and challenges of doing so should be understood.

2 METHODOLOGY

This study adopts a methodological approach to conducting a systematic literature review of the present status, benefits and future challenges of implementing digital technologies in construction health and safety (H & S) in the construction industry. A systematic literature review (SLR) selects pertinent (primary) studies, extracts and analyzes pertinent data from the selected studies to address certain research questions according to a predetermined review protocol and quality procedures (Munaro et al., 2020). This method can be used to methodically infer logical conclusions from the collected material. By doing both qualitative and quantitative studies of digitalisation and construction H & S in the construction sector, content analysis has an edge over other methods (Yang et al., 2021). While conducting a systematic review of the literature, several methods and procedures are used with the same result. (Xiao and Watson, 2019). The research follows procedures that were consistent with the work of (Tjebane et al., 2022).

2.1 *Search strategy*

Data were collected from databases like Scopus, ScienceDirect, Google Scholar, Emerald Insight, Web of Science, IOPscience, and Taylor and Francis. Several search phrases were used to find the pertinent papers. Additionally, the search phrases were combined using Boolean and database-specific operators like AND, OR, and special characters like truncation (*) or (?) (Kugley et al., 2016). The search terms used were; adoption, challenges, digital technologies, construction industry, industry 4.0, factors affecting, health and safety.

2.2 *Inclusion and exclusion criteria*

The most appropriate literature was carefully chosen, screened, and identified using the inclusion and exclusion criteria procedures. The articles were also examined for duplication.

Studies based on the pertinent topic under study were included in this review. Digital technologies in construction health and safety in the construction industry, written in English and published between 2008 and 2021. A total of 673 articles was extracted from the various databases. 38 duplicate publications were removed. The 561 papers were discarded because they either lacked peer review process or were not written in English, and did not emphasis on digital technologies in construction H & S in the construction industry, leaving 74 studies. The abstracts of the 74 articles were read excluding 25 articles as the articles did not focus on safety technologies in construction, and 49 papers were selected for the concluding analysis. The 49 papers were thereby used for the review. Content analysis was used to analyse the data. Figure 1 shows the approach used during the selection of the studies.

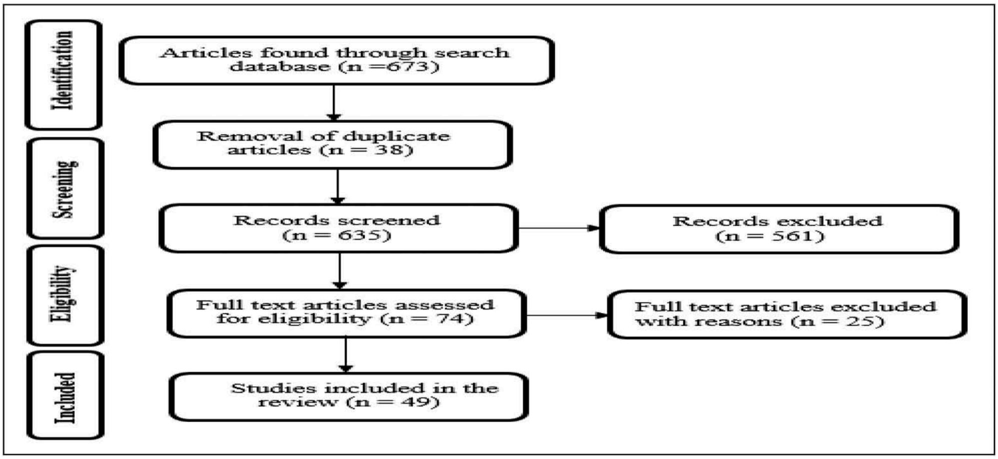

Figure 1. Flow chart showing the systematic literature review.

3 RESULTS

This section presents results from the systematic literature review on the benefits and challenges of implementing digital technologies in construction H & S.

3.1 *Descriptive analysis of the SLR findings*

The result in Figure 2 shows that majority of the papers are journals (86%), conference papers (12%), and book chapters (2%) which represented the main results of the study. Over 20 different sorts of journals made significant contributions to the database. This implied that studies on safety technologies in construction health and safety management have advanced and attracted widespread attention. Figure 2 shows that there was an increase in publications from 2019 to 2021 with 2020 having the highest number of publications while 2011 and 2013 have the least publications. The names of the publications and the number of papers are shown in Figure 4. Some of these publications are listed among the top construction journals by Wing (1997) and include; the International journal of project management, Journal of construction engineering and management, and Automation in construction. There are other journals such as safety science, and Accident analysis and prevention. Other journals concentrate on the use of technology in the building industry namely; Construction innovation, and the Journal of information technology in construction. According to the findings, automation in construction has the highest number of publications which shows its importance in the field of using digital technologies in construction.

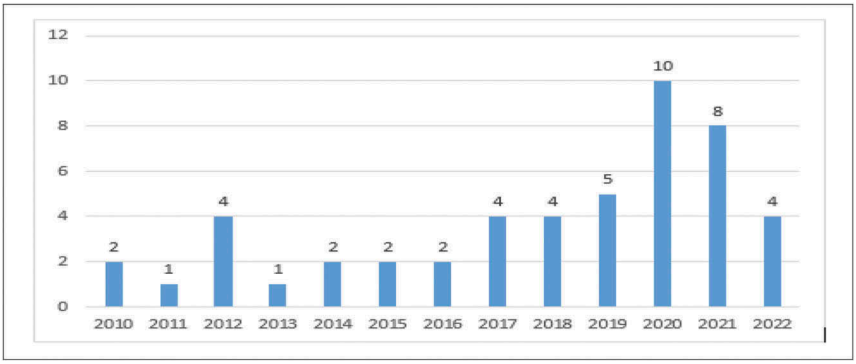

Figure 2. Number of publications between 2010 – 2022.

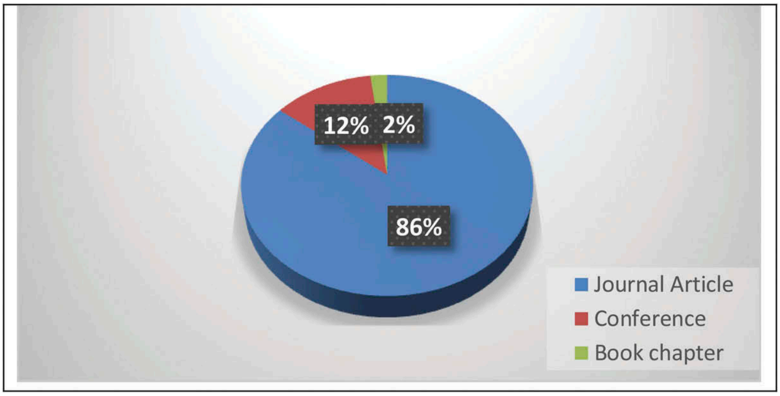

Figure 3. Type of publication.

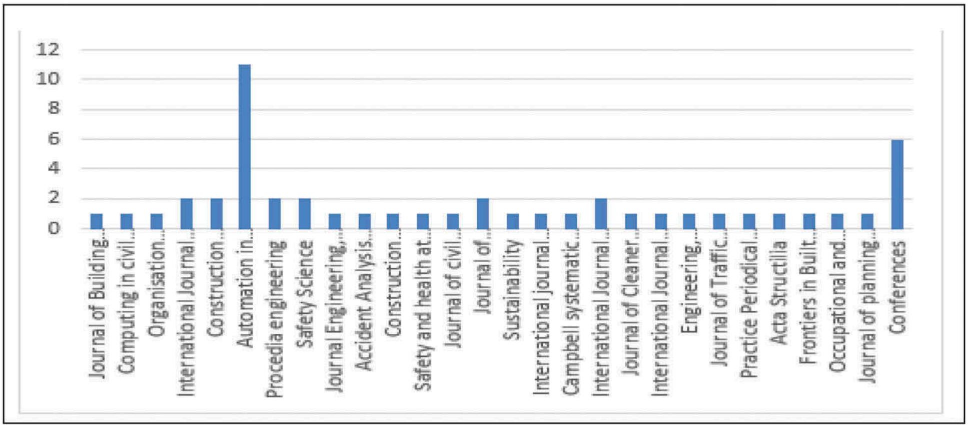

Figure 4. Sources of publications.

3.2 *Benefits of digital technologies in construction health and safety*

This section shows the review of literature of the benefits of implementing digital technologies in construction health and safety.

Table 1. Benefits of digital technologies.

Benefits	Sources
Increased collaboration	Rantsatsi et al. (2020), Boje et al. (2020), Swallow and Zulu (2019), Nnaji et al. (2020), Chileshe and Dzisi (2012), Awolusi et al. (2018)
Reduced safety hazards	Nnaji et al. (2019), Nnaji et al. (2020), Swallow and Zulu (2019), Chileshe and Dzisi (2012), Azhar (2017), Chen et al. (2018), Park and Kim (2013), Nnaji et al. (2020), Yang et al. (2021), Lu et al. (2011), Tender et al. (2022), Shafiq et al. (2021), Guo et al. (2017)
Improved safety inspections	Lin et al. (2014), Irizarry et al. (2012), Okpala et al. (2020), Nnaji et al. (2019), Lu et al. (2011)
Improved productivity	Nnaji et al. (2020), Enshassi et al. (2016), Hammad et al. (2012), Awolusi et al. (2018)
Ability to foresee hazards	Swallow and Zulu (2019), Shafiq et al. (2021), Yang et al. (2021)
Reduce risk factor	Nnaji et al. (2019), Nnaji et al. (2020), Okpala et al. (2020)
Improved budget management	Nnaji et al. (2019), Nnaji et al. (2020), Malomane et al. (2022)
Better risk management	Tender et al. (2022), Zou et al. (2017), Okpala et al. (2020)
Accident prevention	Muzafar (2021), Farghaly et al. (2021), Yang et al. (2021)
Improved health and safety performance	Swallow and Zulu (2019), Malomane et al. (2022), Yang et al. (2021) Lu et al. (2011)
Improved workflow	Lu et al. (2011), Malomane et al. (2022), Swallow and Zulu (2019)
Improved communication	Ganah and John (2015), Swallow and Zulu (2019), Nnaji et al. (2020)
Greater visibility on sites	Malomane et al. (2022), Azhar (2017), Tender et al. (2022)
Sustainability in construction	Abioye et al. (2021), Malomane et al. (2022), Nnaji et al. (2020)
Hazard visualization	Farghaly et al. (2021), Swallow and Zulu (2019), Cortés-Pérez et al. (2020)
Better information management	Azhar (2017), Nnaji et al. (2020), Guo et al. (2017)

3.3 *Challenges influencing the implementation of safety technologies*

This section shows the review of literature on challenges inhibiting the implementation of digital technologies in construction health and safety.

4 DISCUSSION OF FINDINGS

This section presents the discussion of findings from the systematic literature on the benefits and challenges of digital technologies in construction health and safety and the strategies to improve its implementation.

4.1 *Benefits of safety technologies in construction*

Table 1 indicates the benefits of digital technologies in construction H & S. The most beneficial factor are; reduced safety hazards with 13 sources and increased collaboration with 6 sources. This is closely followed by improved workflow, improved safety inspections, ability to foresee hazards, reduced risk-factor, improved budget management, improved project planning, better risk management, and accident prevention. These technologies help organisations plan and manage occupational H and S from the beginning of a project. According to Kanan et al. (2018), these technologies will help organisations plan and manage occupational H and S from

Table 2. Challenges influencing the implementation of safety technologies.

Challenges	Sources
Construction firms' level of interest	Malomane et al. (2022), Yang et al. (2021),Zhou et al. (2012)
Traditional method preferred	Lingard et al. (2015)
The size of projects	Swallow and Zulu (2019), Muzafar (2021), Yang et al. (2021)
Resistance to change	Swallow and Zulu (2019), Yang et al. (2021), Abioye et al. (2021)
Unavailability of resources	Zhou et al. (2012), Malomane et al. (2022), Farghaly et al. (2021)
Inadequate skills and expert knowledge	Farghaly et al. (2021), Malomane et al. (2022), Tjebane et al. (2022), Nnaji et al. (2020), Yang et al. (2021),
Unavailability of funds	Malomane et al. (2022), Tjebane et al. (2022), Yang et al. (2021), (Zhou et al., 2012), Chileshe and Dzisi (2012)
Unavailability of training capability	Malomane et al. (2022), Swallow and Zulu (2019), Yang et al. (2021)
Inadequate finance to implement change	Malomane et al. (2022), Yang et al. (2021)
Lack of access to wireless broadband	Malomane et al. (2022), Ganah and John (2015)
Lack of clients support	Zhou et al. (2012), Nnaji et al. (2020)

the beginning of a project. The findings of Choi et al. (2020) opined that the technologies will help prevent accidents, improves exposure, make monitoring, checks, and balances easier, and improve workflow. This is most likely due to the automated nature of these systems, which can also monitor autonomously and recommend security requirements. Shafiq et al. (2021) also discovered that employing preventive measures that lower injuries and accidents on building sites, and applying safety technologies is crucial for improving construction sustainability. Additionally, the advantages provided by safety technologies may result from their capacity for hazard detection and prevention. The findings supports the research of Malomane et al. (2022) who suggested that the preventive tools make the construction environment a controllable place that prevents accidents. Also, better communication could be achieved when safety technologies is implemented. This corroborates the findings of Swallow and Zulu (2019) who mentioned that adding value through visualization and clearer communication of project outputs, as well as factors that have a beneficial impact on H & S management, such as site design and logistics, are the key perceived benefits of safety technologies. The extant literature revealed that the use of safety technologies can improve the safety of individuals and equipment on construction sites. Literature has shown that accidents, injuries, hazards, and fatalities can be eliminated using technologies such as Building Information Modelling (BIM) (Getuli et al., 2017), Virtual Reality (VR) (Malomane et al., 2022), Radio Frequency Identification (RFID) (Khan et al. (2020), Artificial Intelligence (AI) (Awolusi et al., 2018), Sensors (Zhou et al., 2012), Ultra-Wide Band (UWB) (Okpala et al., 2020), Drones Irizarry et al. (2012), Global Positing System (GPS) (Bejgam et al., 2021), Robot and Automation (Akinlolu et al., 2020), Augmented Reality (Li et al., 2018) among others. These innovations not only help with building projects but also with planning and controlling occupational H and S from the beginning to the end of the project for organisations (Abubakar et al., 2014). On the other hand, Khan et al. (2020) asserted that technologies for safety can assist in keeping an eye on workplace activities, transferring communication, detecting dangerous places, and reporting on potential threats.

4.2 *Challenges affecting the implementation of safety technologies*

According to the result of the literature review, unavailability of funds and inadequate skills and expert knowledge were critical challenges affecting implementation of safety technologies. Other factors are a lack of innovation, a high cost of adoption, a low level of training capacity, a lack of specialized personnel, a lack of client support, lack of financial resources, lack of wireless broadband connection, the scope of the project, the client's inability to provide funding, and a lack of qualified personnel. Implementing safety technologies in the construction industry is perceived to be expensive to adopt and maintain rather than innovate (Malomane et al., 2022). Nnaji et al. (2020) and Malomane et al. (2022) also affirmed that the professionals in the field resist changing their established practices and show no interest in incorporating new technologies. Due to a shortage of qualified personnel, technical expertise, and client disinterest in insisting on and planning the implementation of the innovations, there is a low interest in embracing safety technologies (Malomane et al., 2022). In the same vein, Azhar (2017) noted that key barriers for the construction firms include; a lack of expertise, inadequate access to wireless broadband, insufficient electricity, and inadequate funding. Additionally, because most construction companies are small and medium-sized businesses, it may be challenging for them to integrate safety technologies (Jayashree et al., 2021). These firms may be affected because due to the cost affordability of implementation and maintenance. According to the literature review, implementation obstacles include a lack of education, a mismatch between the supply and demand of labour, and the possibility that some people would lose their employment as a result of digitisation. These issues may be impeding some businesses. Lack of technical expertise combined with a lack of legislation and regulation may be another obstacle to its adoption (Nnaji et al., 2019). Zhang et al. (2021) also asserted that the adoption of safety technologies may be hampered by a lack of understanding of how they operate and the degree of public awareness of them. This degree of knowledge is the result of a lack of knowledge about the advantages of the construction industry. Shafiq et al. (2021) recommended that training, workshops, and seminars could promote the adoption of safety technologies. Case studies could be done, a digital technology module could be added to the construction department, and experts should be trained in the new technologies (Yang et al., 2021). The organisation won't have the necessary skills if these solutions for overcoming these technologies' implementation obstacles are ignored (Malomane et al., 2022) and thus will face difficulties in the future. Likewise, Yap et al. (2022) emphasised that another obstacle to the adoption of safety technology is a lack of a plan for improvement in terms of technical capacity. The findings also indicated that minor obstacles to deploying new technology include a lack of motivation and a shortage of specialists. Furthermore, the findings of Muzafar (2021) concluded that the industry lacks technical personnel to operate these technologies. From the findings, it is obvious that in order to effectively mitigate the negative issues attributed to H & S in the construction industry, the use of safety technologies is paramount. The application of the technologies can then be made possible by increasing the degree of awareness attained through the mode of teaching, the holding of workshops, and the organizing of seminars. Further, institutions of higher education should include digital creative practices in the curriculum to improve skills and knowledge regarding the use of safety technology. Likewise, individuals who are already employed in the field need to receive knowledge and training through formal education or brief courses. The article also suggested using shareholder benefits to promote the use of safety devices.

5 CONCLUSION

The purpose of this study is to offer the vital information needed to enable the adoption of digital technology for improving worker H & S in construction. Benefits and obstacles to the implementation of the indicated technologies were discussed in this study. From the study, the result indicated that the main benefits that could be derived from using safety technologies are attributed to; increased collaboration, better information management, and reduced safety hazards, among others. The challenges preventing the effective implementation of safety technologies are; construction firms' level of interest, the traditional method preferred, the size of projects, resistance to change, and unavailability of resources, among others. In view of this, this study concluded that training and skills acquisition should be provided to construction workers. Additionally, businesses want to switch to leveraging safety technologies to support a more proactive approach to employee development. The majority of construction companies also rely on funding from the government, and the scale of the companies is also important. These construction companies rely on government contracts, which have a set procedure for completion. Therefore, to make it possible for technologies to be deployed, governments must review their processes, directives, and laws. Additionally, most businesses lack the financial resources and are unsure of their ability to sustain the digital innovation process; as a result, careful planning to gather financial resources should be made. To deal with the challenges faced by the industry in implementing the technologies, the government and construction companies should develop plans to embrace and sustain these technologies in the industry. Research in the future should focus on the viewpoint of field workers to produce useful knowledge that will supplement the knowledge in the study.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Barriers to measuring and managing of project success-case study of public sector infrastructure projects in South Africa

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ABSTRACT: This study seeks to identify the challenges of measuring and managing project success from ongoing infrastructure projects and to uncover best practice for innovative project governance. The study adopted a quantitative research approach to gather data through questionnaires. Data was collected only from ongoing construction projects being executed in the Free State province. Data collected was analyzed using descriptive statistics with the aid of SPSS software. The most potent inhibitory factor in the provision of successful public sector infrastructure services and development was determined to be competence related factors and project management factors respectively. The findings of the study reveals that the level of success criticality in the development of construction projects in South Africa is according to the specific responsibilities of management. The novelty of the work stems from its focus on ongoing projects as the measurement of project success usually occurs upon commissioning in a conventional sense.

1 INTRODUCTION

The construction industry plays a major role in the economy as its share of the Gross Domestic Product (GDP) and its interaction with other sectors of the economy. When the project complete on time, on budget and achieves the performance goals, it is considered a success. However, this is not usually the case in developing countries where most projects are not completed on time. Therefore, there is a need for the organizations that is involved in construction pro-jects to come out with the strategies on how to guide the project until it becomes a success in the future. In the construction industry, time, cost, and quality have long been defined as the basic criteria and factors of measuring success. The construction industry by its nature is a complex, project oriented, high risk and competitive business. It is one of the major contributors to the national economy and has a multiple impact on South Africa (Aigbavboa and Thwala, 2014). The construction industry is also the least innovative industry compared to other countries. Construction project failures are increasingly reported around the world and achieving success on construction project is becoming difficult due to finish on time, within budget and at an accepted quality level.

The public sector has contributed to the development of the construction industry in several ways and appeared to be the major provider of infrastructure projects in many developing countries, including South Africa. When compared to other industries, the construction sector appears to be the least innovative on that front. Continuous reports of project failures are incessant globally and the fragmented nature of the construction industry further exacerbates this challenge. Amid the financial year(s) of 1998/99 and 2016-/2017 year of allocation an amount of 2.7 trillion

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to have been spent of infrastructure alone (National Treasury 2018). A plethora of studies has been conducted on project success and project management success (Bilir & Yafez 2021, Irfan, Khan, Hassan, Habib, Khan & khan 2021,). However, there is a lack of evidence of similar studies being undertaken in the Free State province of South Africa.

The objective of this study is identifying barriers on how the measurement and manage-ment of project success during delivery of public infrastructure projects within the Free State province. The study will further recommend the improvement of delivery of the public sector infrastructure projects.

2 THEORY OF PROJECT MANAGEMENT

Project management (PM) has been in existence since the days of the Egyptian pyramids or the Tower of Babel; the Manhattan Project in the 1940s is considered the first application of project management, as it is known currently, with separation of responsibilities between project manager and functional manager (Almeida, 2017). The use of PM has, however, only become fashionable since the mid-1990s (Meredith and Mantel Jr, 2011).

Munns and Bjeirmi (1996) define PM as the process of controlling the achievement of the project objectives, through employment of the existing organizational structures and resources, by applying a set of tools and techniques. Similarly, the PMI (2013) defines PM as "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements". This conceptualization can be supported by arguing that PM aims to meet the project objectives throughout five process groups or phases. These five process groups are initiating, planning, executing, monitoring, and controlling, and closing (PMI, 2013). Finally, Meredith and Mantel Jr (2011) suggest that PM provides an organization with tools to improve the ability to plan, implement and control the ongoing activities. Although conceptualisations of the concepts of the project and PM are oriented towards completion of an endeavour, the term "project" denotes selection of an activity or task to benefit the company, while the term "PM" refers to planning and control (Munns and Bjeirmi, 1996).

In the 1990s, traditional project management received increased criticism for its lack of impact and benefits (Aziz, 2013). Moreover, Morris (2010) contends that project management theory remains "stuck in a 1960s-time warp". Barnes (2002) connotes that a theory-based approach is necessary for developing project management further: "We enthusiasts for project management have a choice. We can already manage projects well – not always, but we know how to do it.

Following a similar line of thinking, Koskela and Howell (2002) dispute that "the underlying theory of project management is obsolete". Harsh criticism is evident, but this criticism may also become the primary basis for identifying new ways of managing projects and/or integrating existing ways for managing projects. As mentioned by Winter and Szczepanek (2008), the pattern now emerging in research on project management around the world is one of increasing concern about the relevance of conventional project management theory and how it relates to the growing practice of managing projects across different industry sectors.

2.1 *Dimensions for measuring construction project success*

Most of the researchers have grouped success criteria into different components of project success for which they often refer to dimensions. Baccarini (1999) Proposed two distinct components (project success and project management success) of project success. According to Slevin and Pinto (1986) project success is suggested to have two major components: issues dealing with the project itself and issues dealing with the client. However, in recent literature, many types of categorizations could be observed. As examples, Shenhar et al. (2001) mention that there are "four major distinct components of project success: (1) project efficiency (2) impact on the customer (3) direct business and organizational success, and (4) preparing for the future". Wai et al. (2013) present five components for a building project from the developers" perspective. They are (1) company success (2) profitability success (3) primary product success (4) secondary product success and (5) branding success.

Project success, project management success and project performance are sometimes a bit confusing because, these words have been used in different ways by different researchers in the literature. Project performance often refers to project management success. Semantically, project success is measurable only after the project is completed Morris and Hough (1987), while project performance is measured during the life of the project (Cooke-Davies, 2002).

The concept of success in a construction project, according to some researchers, is corresponding to efficiency and effectiveness measures (Ika & pinto 2022,).

Key participants of a particular project, on the other hand, are fully responsible for efficient and effective execution of the project. From the contracting company point of view, contracting company has to ensure the achievement of predetermined performance objectives and expectations of main participants. Therefore, construction project success could be viewed as the degree of achievement of efficiency (short-term perspective) and effectiveness (long-term perspective) objectives of execution of a project (Pereira, Varajao & Takagi 2022). Moreover, Serrador and Turner (2014) have investigated to what extent project efficiency is correlated with stakeholder satisfaction and overall project success. Through a survey of 1,386 projects it was found that project efficiency is, 60% correlated with stakeholder satisfaction and 56% with overall project success. They further stress that their findings corroborate with the findings of Turner and Zolin (2012) that project efficiency is an important contributor to stakeholder satisfaction and overall project success but shows quite clearly that other factors contribute significantly to both.

2.2 *Success criteria*

According to Ika & Pinto (2022) and Irfan et al., (2021), project success criteria as the measure by which an individual judge success or failure. Bilir & Yafez (2021) denote criterion as

Table 1. Success criteria.

Criterion	Meaning	Measurers
Cost/Budget	The degree of compilation of construction work within the estimated budget.	The measure of cost can be in the form of unit cost, and cost overrun
Time/Schedule	The degree of compilation of construction work within agreed/approved duration.	The measure of time can be in the form of construction time, speed of construction and time overrun
Quality	The degree of conformity to all technical specifications	Measured subjectively using a point scale
Safety	The degree to which the general conditions promote the completion of a project without major accidents or injuries	Measured in terms of accident rates, safety trainings, safety signs and precautions taken to avoid hazards.
Client/Customer Satisfaction	The degree of satisfaction over the achievement of client's expectation in executing the project	Measured subjectively using a point scale.
Employee/ Project Staff Satisfaction	The degree of employee job satisfaction	Measured subjectively using a point scale.
Cash-flow Management	The availability of adequate funds to carry out construction work without interruptions.	Availability of a positive or negative cash-flow balance at any given time is an ideal measure.
Profitability	Degree of financial success of the project	Profitability can ideally be measured as an increment by which revenues exceed costs.
Environmental Impact	The degree of negative impact causing to the environment due to the execution of the project.	Environment impact can ideally be measured subjectively using a point scale.
Learning and Development	The degree of improvement in terms of new knowledge and expertise, level of professional development and exploitation of new technology.	Measured subjectively using a point scale

(Lim and Mohamed, 1999, Chan and Chan, 2004, Haughey, 2014, Hughes et al., 2004, Al-Tmeemy et al., 2011, Heravi and Ilbeigi, 2012, Chovichien and Nguyen, 2013, Serrador and Turner, 2014) a principle or standard by which anything is or can be judged. Pereira, Varajao & Takagi (2022) describe project success criteria as the set of principles or standards by which auspicious outcomes can be completed within a set specification. For the purpose of this study, description used by both (De Wit, 1988, Cooke-Davies, 2002) will be used. The criteria for measuring project success must be set out at the commencement of the project (Pereira, Varajao & Takagi 2022). Similarly, Frödell et al. (2008) discuss the characteristic of a measuring system; simplicity in use, credibility in results, fast feedback, action orientation, economical and efficient, few measures, broad collection of data and broad feedback. Table 1 outlines criterion and yardstick for project success.

3 RESEARCH METHOD

Saunders et al. (2009) denotes that research can follow either a quantitative or qualitative approach (or both), and this study will utilize the quantitative approach. The Quantitative methodology generates data, which can transform into numerical and statistical forms. The quantified information can then be imperilled to a thorough quantitative assessment in a formal and rigid fashion. Quantitative approach can further sub-categorize into inferential, experimental and simulation approaches, and its purpose is to form a database, from which to conclude on the characteristics or relationships of a population (Kothari, 2004). This approach is primarily used to investigate the existing conditions and interactions of employees, and a confidentiality agreement will be signed to protect the rights of the participants and to assure them that the information will be solely used for the research purpose. The scholars reverberate that a large sample size does not guarantee accuracy of findings if the study is not meritoriously designed, because of the increased prevalence of errors and biases in such a study. The object population of the research was defined as those individuals in management positions at a firm that carries out infrastructure development for the public sector. Brink et al. (2012) purports an existence of distinction between the object and reachable population. The latter defines the group of units as that, which encompasses the specific interest boundaries of the study. Therefore, in the present study the reachable population refers to the population of Quantity Surveyors, Engineers, Project Managers, and Contract Managers in the Free State province. This study used a non-probability sampling strategy in the selection of the firms and participant employees. The firms were selected from data in the municipalities, which contained information of firms that were engaged in public infrastructure projects. This then entails that the firms were selected using purposive (judgemental sampling). This non-probability sampling method ensures that the researcher collects data from participants from selected participants in order to have a sample of specific cases. The questionnaires were disseminated to the firms where any member of the staff of the firm in top management of public sector infrastructure projects were able to complete the questionnaires.

The sampling method at this stage was convenience sampling which according to Brink et al. (2012) "involves the choice of readily available participants". Moreover, Brink et al. (2012) state that there should be "at least 10 participants per variable". The study comprises of four main problem variables that management encounters in their efforts for successful infrastructure development, technical, contextual, competence and project management problems. The study comprises of 27 participants from 10 selected firms, which equates to a 1:6,75 variable to participant's ratio, which though lower to the recommended ratio, is significantly close. Primary data was collected by means of questionnaire survey from relevant construction sites; through emails, telephone, as well as by scheduling appointments. The data required to be collected from construction project managers was segmented according to the findings of literature and segmented into distinct success variables. Thirty-five items were identified to measure the success of the project. The identical items were then integrated into similar sections of which four principal categories developed (technical, contextual, competence and management). These categories are in line with the previous studies conducted by similar scholars in the field (Hughes et al., 2004, Arendse, 2013). The research tool of the study was a questionnaire that contained two sections. Section A collected demographic data of the participants. Section B measured the perceptions of the participants in a 5-point Likert scale method. Section B was sub-divided into four sub-sections focusing on the variables of the study. The research tool is designed according to previous design by Hughes et al. (2004) of a Construction Project Success Survey (CPSS) to measure the success of an infrastructure development project. There was a 90% response rate in the study with all 27 of the 30 questionnaires returned completed appropriately without errors or omissions. In a previous related studies, Takim et al. (2004) investigated performance measurements in the construction projects in Malaysia" and had a 20.9 percent response rate. Adnan and Morledge (2003) also received a relatively low response rate of 20 percent. The collected data was translated into numerical evidence, that was analysed using descriptive statistics. The data analysis concentrated on providing evidence of the important associations of variables linked to success of the completion of public infrastructure projects. The descriptive statistics analysing the variables was then used to accept or reject the study hypothesis statements. However, this is a pilot study and therefore hypothesis statements do not form part of the findings. Responses to each question were converted to numerical figures in accordance to the degree of agreement or disagreement. The overall scores per variables section (Competence, and Management) were given mean values that were then scaled in accordance with numerical value. Additionally, each question carried a measure of importance measurement, where the different level were given numerical values (L=1, M=2, H=3 and N/A=0). The numerical values of the individual aspects were then calculated in order to assess the aspects which management valued as most to least important. Each question in the second section of the questionnaire was assessed based on the five-point Likert scale (scores of -2 - +2), where „strongly disagree" (-2) and „strongly agree" (+2) were the extremities. The questions used were „close-ended" and the data collected was analysed using SPSS version 20 descriptive statistics.

4 PRESENTATION AND DISCUSSION OF RESULTS

The data collection process was conducted over a period of six weeks. The most prevalent gender in management in the construction industry is male. This concurs with evidence provided by other scholars (Hughes et al., 2004, Sezer, 2014, Ramlee et al., 2016) who also identified domination of the male gender overall, from lower hierarchy to top management in the built environment industry, see Figure 1.

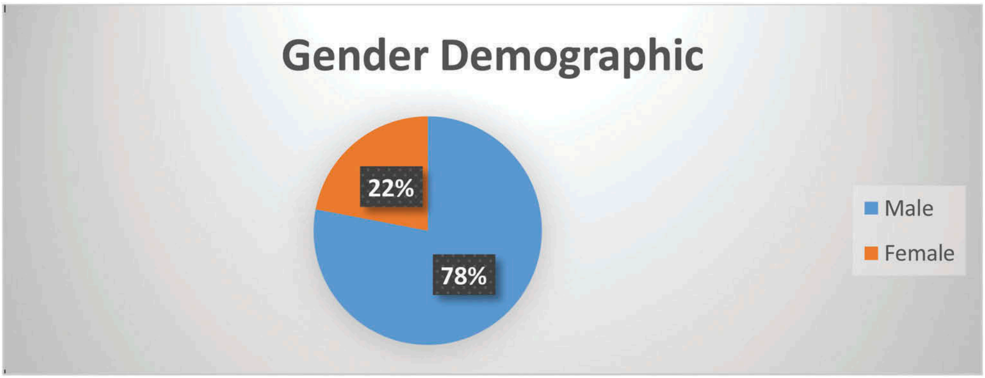

Figure 1. Gender demographic.

The mean years of experience from all the participants was 13 years 6 months highlighting great degree of experience in the industry among the respondents. The long period of experience was linked to an average of 20,68 infrastructure projects which translate to an average of close to 2 projects per year. The management personnel were qualified, with (33.3%) holding at least an Honour's Degree and (11%) holding doctorate degrees. Figure 2 below highlights the distribution of educational qualifications amongst the population.

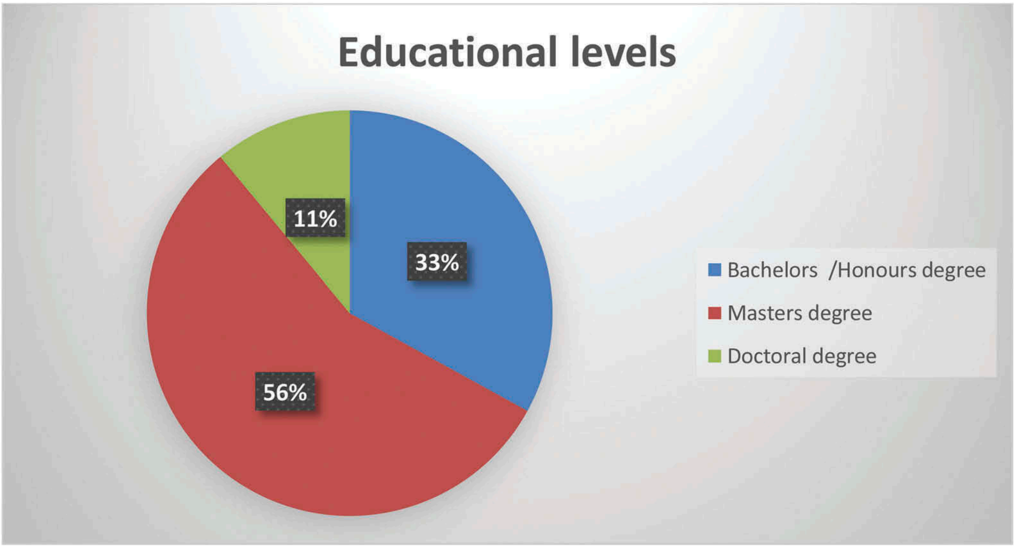

Figure 2. Educational levels.

5 PROFESSIONAL COMPETENCE RELATED PROBLEMS

The competence factors comprised of five questions that measured variables of professionalism, budget contingence, supervision, involvement and training and experience during projects (see Table 2 below). 100% of respondents highlighted that there was professional conduct in their corporate processes, and this was of considered of critical importance (mean = 2.9) to project success. Generally, competence contributors were all ranked highly (overall mean = 1.84) which can be concluded that management highlighted the importance of knowledge, skills and ethics in order to successfully complete projects. Ability to competently manage budget contingencies was the lowest ranked competency factor while it was regarded of critical importance (mean = 2.9). This highlights that though management is generally satisfied with their financial planning and are realising profitability from their projects, the general perception is that there is more that can be done to improve financial planning.

Factor	Mean Value	Importance (Ranking)
Professionalism	2.0	2.7 (3)
The training and experience gained on this project by the project team is carried forward to improve future projects.	1.9	2.8 (2)
Availability to design robust plans and manage changes	1.8	2.8 (2)
Involve participants	1.7	2.7 (3)
Budget contingencies are well managed	1.6	2.9 (1)
MEAN VALUES	**1.78**	**2.82**

6 PROJECT MANAGEMENT-RELATED PROBLEMS

The management sub-section comprised of 10 questions regarding aspects of leadership, team management, planning, strategic approaches, resources acquisition and management and communication. The general trend in the management contributors is that the participants reported completion of the contributors as well as placing high importance in the category variables. 100% (27) respondents reported on effective strategic management processes and efficient planning and management of project financials. The prioritisation of profitability of projects by management can be highlighted by the fact that all 27 respondents (100%) reported highly on financial reporting processes and their importance (mean value of 2.0 and 3.0 respectively).

Table 2. Project management related factors.

Factor	Mean Value	mportance (Ranking)
Strategic management processes to the master schedule	2.0	2.9 (3)
Planning and Management of project financial demands	2.0	3.0 (1)
Managing time with project goals, targets and expectations	1.9	3.0 (1)
Development, Outlining and communication of Project requirements	1.9	2.9 (3)
Provide direction to staff and anchoring parties	1.9	2.9 (3)
Plan quality control	1.8	2.8 (6)
Management of project economy	1.8	2.8 (6)
Handle the portfolio management processes	1.8	2.6 (10)
Plan detailed time schedule and resources	1.7	2.8 (6)
Analyze the project process and the environment	1.7	2.9 (9)
MEAN VALUES	**1.91**	**2.87**

7 DISCUSSION

These results show that the infrastructure development in South Africa is currently generally satisfied with their management performance and that adaptation to contextual problems is considered to be the biggest problem hindering projects‟ success. The results of the study showed that accurate and effective pre-planning was amongst the most critical technical contributors to successful project completion according to management The findings highlighted that effective strategic management processes and efficient planning, and management of project financials was considered the most critical variables of success similar to the study of (Pereira, Varajao & Takagi 2022). Management has been extensively researched and the relative importance highlighted to be key for the success of public sector construction projects. Literature suggest that efficient and effective management enables for robust monitoring and evaluation systems (Ika et al. 2012; Alinaitwe and Ayesiga, 2013), coordination and integration of project activities (Tan and Ghazali, 2011), effective communication between teams and stakeholders (Omran, et al. 2012), effective project scheduling and budgeting, adequate team selection, training, development and motivation, project managers competence and decision making skills (Adnan, et al. 2014; Saqib, et al. 2008). Generally, competence contributors were all ranked highly, and management highlighted the importance of knowledge, skills and ethics in order to successfully complete projects. This is in contrast with the evidence provided by Praveen et al. (2013) who highlights that there is a great extent of skill shortage in South Africa and other countries, which significantly affects construction projects‟ success. Similar situation exists in many. Management were also critical regarding employee technical efficiency in task performance and the technical ability to use the appropriate devices and systems for systematic processing handling of project tasks and data. This concurs with the evidence provided by Nasir and Sahibuddin (2011), who reverberate that project success is directly dependent on employee's proficiency. Sezer (2014) adds that modern technology has provided tools and systems that should be taken advantage by contractors in order to reduce the timescales of project while maintaining significant success levels.

The findings from the research study highlighted that management are cognisant of the existing poor hierarchy structures in their projects operations, signifying the lack of structural order to be the greatest deterrent factor to successful project completion. Scholars (Ika et al. 2012; Haughey, 2014; Sezer, 2014) generally agree that the involvement of multiple stakeholders in construction projects demands that all parties are aware of their responsibilities in order to reduce the chances of conflict or confusion.

8 CONCLUSION

Competence and management contributors were considered to be the most relevant success contributors while contextual factors had the least effect on success. Success measures were conducted in terms of two of the four principal factors and associated variables, competence and management objectives. Literature has shown that the related concept of a successful project have multiple beneficial outcomes. Strategic operations and data collection and processing enable for efficient and effective practices through deliberate planning and learning and development. The direct outcomes from the infusion of the various constituents are realisation of greater profit margins, client satisfaction, improved corporate relationships and systematic implementation of the operational advancements that are suitable to contextual demands. Recommendation is that It is of critical importance to ensure that various parties involved in projects (project manager, engineering manager, customer, and other partners) have a healthy relationship in order to have a undisturbed flow of stages and that the various parties get the chance to reconcile their views post-project to find areas of success and those that need improvement.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Challenges associated with tender documentation during contract management on public sector projects

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ABSTRACT: Public sector funds are often wasted through mismanagement of projects and unethical practices. This study investigates challenges associated with tender documentation during contract management which make public sector projects susceptible to mismanagement of funds and how to mitigate such. An empirical study conducted through a case study approach used documents and interviews. Both of these were purposively selected and included school building projects and professional service providers and contractors, with hands-on experience. Findings include that; relatively inexperienced officials were in charge of producing most tender documentation, impacting the overall cost and time overruns. Further, mismanagement of project management areas and unethical practices compounded wasteful expenditure on the projects. The study concludes that producing quality tender documents is likely to reduce fruitless expenditure. It recommends that adequate technical expertise be involved in preparing especially multi-million Rand tender documentation for enhanced compliance and effective utilization of public project funds.

Keywords: Contract management, Cost overruns, Infrastructure procurement management, Tender documentation, Unethical behaviour

1 INTRODUCTION

Literature indicates that generally, the public sector is fraught with challenges associated with cost and time overruns in construction projects. This has been globally recognised in the construction industry, where strategies need to be implemented to reduce rework and improve project performance (Emuze & Smallwood, 2012). At national level, Fengu (2018) states that the Free State and the Northwest provinces of South Africa were in terrible financial state due to delays in the completion of projects, payments without evidence of delivery and allegations of fraud. These claims are supported by the Department of Basic Education (2018), whose report on the education infrastructure grant expenditure stated that supply chain management processes were the leading cause of construction delays.

Alinaitwe, et al., (2013) found that changes in scope which resulted in cost overruns were either due to incomplete designs or the lack of clients understanding of the consequences on cost and time related to their request to change the scope. It is therefore essential that changes required on a construction site which have substantial financial impacts are either prevented through adequate initial planning or thoroughly communicated to the client in advance so

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that they understand the impact of the change and ensure that enough funds are ring-fenced for successful completion (Alinaitwe, Apolot, & Tindiwensi, 2013).

Previous studies show concern regarding the construction industry's perceptions and reputation of various stakeholders relating to money being recurrently wasted through unethical business practices on public sector funded projects (Aigbavboa, Oke, & Tyali, 2014). Money wastage can be related to the unsuccessful implementation of planned scope due to lack of a well-defined initial scope covering the needs of the stakeholders and carries the risk of site abandonment due to an inadequate scope and cost management (Fageha & Aibinu, 2012). Related problems which need to be addressed involve areas of poor planning such as the contractual documentation and ethical behaviour which have an impact on how projects are planned initially (Aigbavboa, Oke, & Tyali, 2014).

Literature indicates that construction projects are confronted with challenges of cost and time overruns (Aigbavboa et al., 2014; Alavifar and Motamedi, 2014; Bhargava et al., 2010; Senouci et al., 2016). The present study views procurement as an important area in construction project management as it affects the scope and cost management of a construction project which may result in opportunistic behaviours to exploit public funds (John and Itodo, 2013). Previous stuides show that one of the reasons for scope changes is due to incomplete tenders and bidding with unfinished plans (Rosenfeld, 2014). However, previous studies only elaborate on the intervention of general project management and not on specific areas within the procurement stage of a project which can lead to loopholes resulting in cost overruns or a waste of public funds and thus remains a problem. This area has been under-researched in previous studies, a knowledge gap to which the present study will contribute. The study aims to examine where the problem in procurement documentation management lies and ways to improve that in future projects to limit cost and time overruns. The study provides valuable insights and guidelines to contractors and clients on minimising cost and time delays on construction projects. It highlights ways to realign the tender documentation to reduce scope variances and minimise the presence of unethical behaviour or practices.

2 LITERATURE REVIEW

2.1 *Project scope and stakeholder management*

As with most countries globally, procurement in South Africa has the potential to create significant change in the economy as state procurement amounts to at least 14% of the Gross Domestic Product (GDP), thereby acting as a catalyst for social and political change (Hart, 2016). Appropriate implementation of procurement systems is vital for all construction projects as it can pave way for matters concerning cost and time management in all phases of any infrastructure-related project (Thwala and Mathonsi, 2012). The construction industry is complex, as changes continuously arise throughout all phases of the construction life cycle. If not adequately managed, the changes can significantly impact on a project's time and cost performance (Senouci, Ismail and Eldin, 2016).

The problem of time delays in projects has adverse effects on the time, quality, and cost of projects especially in the public sector (Alavifar and Motamedi, 2014). The use of correct project management principles and close monitoring and controlling of scope management at the initial planning stages of a project should act as a guide to the cost and time needed to complete the scope (Bhargava, Anastasopoulos, Labi, Sinha and Mannering, 2010). Changes in scope which resulted in cost overruns are mainly either result from incomplete designs at inception or the lack of clients' inputs during the design phase, due to inadequate understanding of the consequences on cost and time when scope changes are requested late in the project life cycle (Alinaitwe, et al., 2013). Unfortunately, the problem of scope management goes hand in hand with poor planning of contractual documentation. It is sometimes directly linked to ethical behaviour, which impacts on project planning (Aigbavboa, Oke and Tyali, 2014). In unethical practices, some individuals tend to use inadequate tender documentation in the public sector systems to exploit the use of public funds for personal gains (Wang and Buckeridge, 2015).

A project manager as the one who leads the team should have reliable support staff, good communication channels and strategic discipline as is the link between the strategy and the team to enforce a schedule and ultimately responsible for achieving objectives (Project Management Institute, 2013). Research highlights the importance of proper cash flow and scope management on a project aimed at factors causing cost overruns (Rahman, Memon, & Karim, 2013; Zimina, Ballard, & Pasquire, 2012). A gap exists in terms of how to better manage these areas at tender stage to avoid the consequences of costs and time on public financial expenditure and delivery of required infrastructure such as schools. Unethical practices by some individuals tend to use inadequate tender documentation in the public sector systems to exploit the use of public funds for personal gain (Wang & Buckeridge, 2015). This can be interpreted as one of the most insufficient areas of project management as it shows how the mismanagement of direct elements of procurement, such as tender documentation, can lead to the cost and time overruns of construction projects in the public sector.

2.2 *Contract management*

Construction contracts promote proper contract administration, minimise disputes and provide quick and easy-to-use resolutions in the event of disputes arising (Thomas and Wright, 2016). Nabet, Eidash, ElMohr and Mohamed, (2017) assert that adequate contract documents save construction time, facilitate effective use of resources and prevent disputes caused by scope creep. In South Africa, the Joint Building Contracts Committee (JBCC) contains a clause relating to the adjustment of preliminaries due to changes in the contract which makes provision for adjusting costs related to the value and time changes on a contract (JBCC, 2013). The additional cost for the adjustment of preliminaries will result in unforeseen expenditure by the client. This theory is supported by Burtonshaw-Gunn (2009), who claims that project cost management is essential throughout the entire project but even more critical before the commencement of a contract.

Morton (2015) states that a professional project manager or principal agent is an entity appointed and authorised by a client to manage and administer the building contract. Other duties include acting on behalf of the client for the success of a project so that contractual matters are handled professionally and in the best interests of the employer's rights and obligations (Shrestha and Martek, 2015). A sound summed-up explanation of the responsibilities involved in the principal agency is the provision of completing transactions on behalf of a client in three ways; to measure the performance of the contractor against agreed commitments; adjustments of details of the contract, and the first line of a dispute between a client and the contractor (Winch, 2010). However, an alternative approach is to study how professional consultants' mismanagement can affect project delivery in terms of time, cost and time. This study looks at some of these issues and how they impact the overall cost.

2.3 *Procurement management systems*

Correct procurement management systems applied at the procurement stage satisfy the objective of efficient financial management and desired outcomes of serving the needs of the project end-user (Van Wyk, 2014). Risks associated with construction procurement are far more complicated than that of goods and services, and for this reason, it requires supply chain management policies (Phillips, 2012). These include infrastructure procurement strategies, correct packaging, pricing and contracting and thorough risk analysis for the prospective contractor to be in place prior to the appointment of a contract such as this (Salah and Moselhi, 2016). In a study by Phillips (2018), it was found that a significant part of the problem emanated from accounting officers not paying enough attention to the lack of intellectual abilities of the officials of public sector departments dealing directly with supply chain management practices and principles of procurement. The root cause of this problem is that accounting officers are not reprimanded enough for their negative findings and are often allowed to keep their positions without resolving issues such as appointing the right people who can produce an acceptable level of quality in bid documentation prior to the advertising of tenders (Phillips, 2018).

Lack of coordination and integration concerning a high standard of documentation at the supply chain level has resulted in extensive rework, defects and quality work at the construction stage (Emuze and Smallwood, 2012). Furthermore, the South African construction industry has been known to have a poor reputation due to its inability to adequately apply clauses within the contract to reduce or apply consequences of non-performance on construction projects once the contractor has been appointed (Othman and Harinarain, 2009). This part of supply chain management can be seen as the current problem's route as it accounts for a significant portion of the GDP and is the most vulnerable to corruption (Nqwakwe, 2012**).**

3 METHODOLOGY

A qualitative approach was adopted which used multiple case studies to obtain an in-depth understanding of the phenomenon under study (Mitchell and Jolley, 2010; Yin, 2018). Case studies are used in many situations to gain knowledge about an individual, an organisation, a group, or a social or political phenomenon (Yin, 2018). This is achieved by investigating a "case" while retaining a holistic and real-world perspective (Yin, 2014). The use of a case study was best suited to explore the problem identified, which is part of pre-tender documentation as a cause for cost and time overruns on projects (Vehovar, Toepoel and Steinmetz, 2016).

To be selected, the case studies had to be located within South Africa. The selected case studies involved three school projects. These were chosen based on a non-probability purposive sampling strategy to inform the study (Leedy and Ormrod, 2015). The non-random inclusion selection criteria focused on projects currently near completion and involved the construction of school projects that started simultaneously and were placed under the same conditions (Creswell and Plano-Clark, 2018). The case studies were fit for the purpose of the study and provided opportunities to identify how the projects reacted to similar situations to enable a comparative analysis (Creswell, 2009). The research design choice for the present study was predominantly based on the convenience of the research instrument having time-saving and cost-efficiency factors, as well as finding results based on facts rather than only opinions. Due to ethical reasons, the identities of the selected projects and/or implementing agents could not be disclosed. To maintain anonymity and confidentiality, letters of the alphabet A, B & C were used while for the interviews, their profession as well as numbers were assigned (e.g Project Manager 1, Quantity Surveyor 1).

Case study documents and semi-structured interviews were conducted with officials, professional service providers and contractors who worked on the construction of school projects. These were selected using purposive sampling based on their knowledge, experience and involvement of the case study projects. The data were analysed manually using themes which emerged from the study.

4 RESULTS

4.1 *Capacity of officials*

The study found that the supervising team had 5 unregistered project managers, 3 professional architects, 3 professional quantity surveyors, 7 candidate quantity surveyors, 5 unregistered civil engineers, 1 registered and 1 unregistered electrical engineer, 1 registered and 1 unregistered mechanical engineer and 7 Supply chain officials. These were responsible for the designs, management and completion of projects as well as the implementation of client departments.

The total number of projects that the department under study was currently running amounted to 55 at different stages.

From the above finding, it is evident that there is not enough capacity to manage the workload by these officials. However, more importantly, none of the appointed project managers had the relevant qualifications or necessary professional registration to manage a project from inception to closeout effectively. It was also found that the officials did not have the expertise to provide enough relevant data to guide the tender process and ensure that the tender amount would not change randomly. Having such in place could play a significant role in following correct project procedures and providing quality documentation to protect both client and contractor from scope creep and fruitless expenditure.

4.2 *Cost overruns*

In terms of appointments, it was found that the contractor for Project A was appointed in February 2016, and contractors for Project B and C were appointed in January 2015 respectively. Each school had been given an 18-months contract. The contract sums are depicted in Figure 1. The findings revealed that none of the appointed tenders on each project had an entire team of professionally registered technical members, especially project managers and quantity surveyors. The findings suggest that the appointment of the service provider did not seem to align with the procurement regulations set out by the Construction Industry Development Board (CIDB, 2011). Wang and Buckeridge (2015) claim that instances which go against policies and legislation are known as unfair tendering procedures. It was found that the tender provided basic layout drawings, a vague scope of work and no site information. The findings suggest that the design team would not be able to deliver value for money which would impact on the reputation and client influence (Awosina, Ndihokubwayo and Fapohunda, 2016). Le et al. (2014) argue that instances such as these give rise to unethical practices, which include deceit and misinformation in the designs and bills of quantities, which would require variation orders and, in turn, push up professional fees.

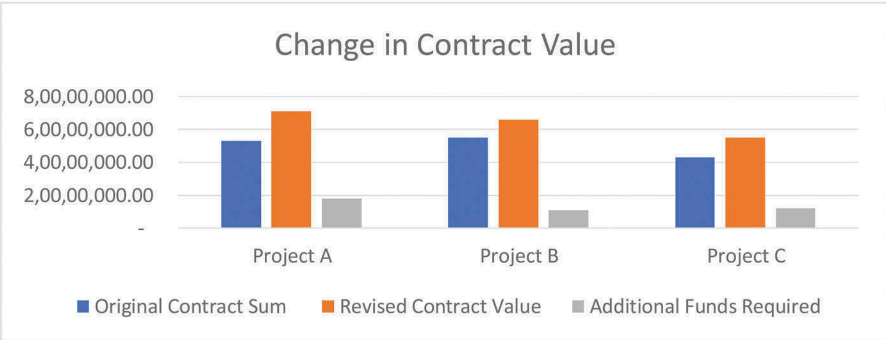

Figure 1. Cost overruns on projects A, B and C.

From Figure 1, Project A contract value increased by R17 Million, Project B by R11 million and Project C by R12 million. Further, the findings show that the revised contract values were about 20% more than the original contract sum as all three projects had severe cost overruns. Project A had cost overruns related to unforeseen ground conditions. In traditional projects, quantity surveyors can provisionally measure instances where circumstances below the ground may be subject to slight change (Sigle, Edwardes, de Villiers and Meyer, 2015). However, this was an all-inclusive contract where the service provider was not allowed to price accordingly, which resulted in a significant cost implication. Project B had also been given a site which was not ready for construction; these circumstances could have been better managed at the procurement stage, where correct contract management would have satisfied the objective of efficient financial management and the end-users needs (Van Wyk, 2014).

Project B and C had similar causes for cost overruns in that their scope of work at the tender stage did not meet the client's needs. The findings support the literature which suggests that the root cause of poor-quality bid documentation emanates from the disregard for the intellectual capabilities of officials in charge of these sections (Phillips, 2018).

4.3 *Time overruns*

The findings show that Project A had lapsed its time for completion by 93%, Project B by 95% and Project C by 107%. Figure 2 shows that the time overrun on all three projects was above 90%. Projects A and B had time overruns caused by late approvals of contract instructions and the client's delayed payments. It was found that Project A did not claim any revisions for practical completion as they were aware of the penalty clause being removed from the procurement documentation and knew they were not at risk of being held accountable. The purpose of having a building contract to balance risk and establish consequences, as claimed by Cooke and Williams (2009), was thus disregarded at the start of this project. However, Project B did use the clauses which remained in the contract for claims to revise the contract period when it would put him at an advantage of claiming additional costs in line with the late approvals, variations and payments. From the literature, cash flow is the lifeblood of a construction project and is vital for its success of a project (Harris and McCaffer, 2013). Project B and C claimed additional time for many variations added to the contract due to the inadequate initial project scope.

Delays in time contribute to many unforeseen costs for the client as the contract allows for revision dates with cost to assist the contractor in completing (Marzouk and El-Rasas, 2014). The study found that Project C had further time delays caused by site abandonment of the contractor due to non-payment by the project manager. Williams (2009) explains that late payment can be found in instances of mistrust between professionals and contractors. Project C appointed a project manager as the head of their project, where delays caused by the subcontractor leaving the site were never addressed as the project manager did not work in the interest of the client but rather themselves. The study further found that the tender document had a flaw which allowed any service provider to be appointed as the head of the team. This was dangerous because the project manager was no longer an agent to the client in charge of administering and managing the project for successful completion or in the employer's interests (Morton, 2015).

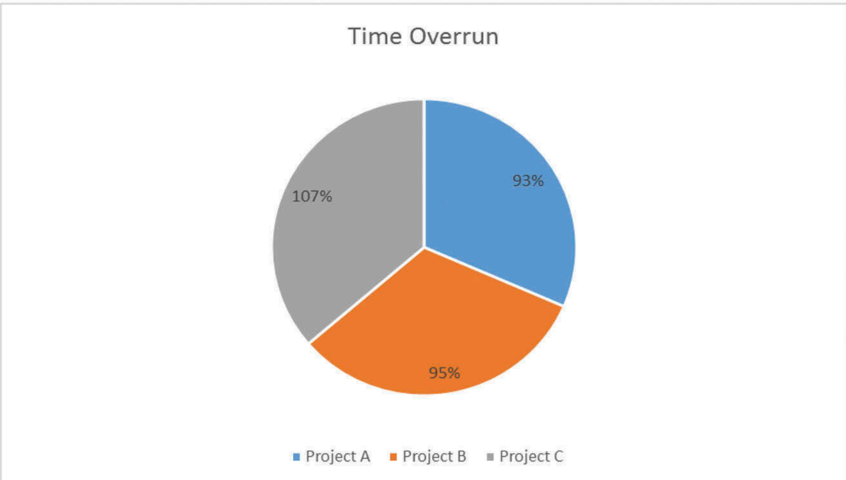

Figure 2. Time overruns on projects A, B and C.

4.4 *Procurement and tender process*

The supply chain management interviewee explained that the infrastructure knowledge is more complex, and they have trouble effectively evaluating tenders and understanding technical principles. The interview indicated that although they request technical staff to be present in this process; it is however, denied without reason. The project manager and quantity surveyor confirmed that this was an issue which caused cost and time overruns. Areas in the tender that were missing were important contractual clauses such as penalties required to protect the client. This finding suggests that supply chain management as a strategic tool for procurement policies is insufficient where there is a lack of capacity, knowledge and inadequate planning, monitoring and evaluation (Ambe and Badenhorst-Weiss, 2021). Another delay noted by the quantity surveyor was the appointment of service providers who were not professionally registered. This finding relates to the improper handling of contractual matters of time and cost variances as they are unaware of the correct manner to deal with these occurrences (Morton, 2015). The findings were similar across the case studies.

4.5 *Ethical behaviour in construction*

The quantity surveyor interviewee mentioned that many of the service providers appointed attempted to take advantage of variation orders by allowing for incorrect quantities, increased rates or areas that should have been allowed for as per the original scope. The loophole created in such instances allowed for ethical misconduct related to greed, and the most unfortunate part of it resulted in the dissatisfaction of clients, poor quality, which affects the end-user, and sadly, deterioration of the profession (Aigbavboa *et al.*, 2014). The quantity surveyor also found it unethical that no measures had been taken to use the contract against defaulting parties by issuing them warning letters or termination. The South African construction industry is known to have a poor reputation due to its inability to adequately apply clauses within the contract on the consequences of non-performance on construction projects (Othman & Harinarain, 2009).

5 DISCUSSIONS AND IMPLICATIONS

The results show that those in charge of preparing the tender documents did not have the necessary knowledge or expertise to develop good-quality documents. It was indicated that officials in supply chain management did not understand all the complexities involved in the construction tender process, and the project managers appointed do not have enough project management experience for these types of contracts. Findings show that inadequate information provided to bidders at the tender stage resulted in offers which did not cover all the needs required to complete the projects within the desired cost and time. The results also show that the tender documents required detailed designs only after the bid offer was accepted. For this reason, certain contractors were priced highly for specific items. This became a source of concern because it left room for the team to collude in installing inferior quality at the construction stage, compared to what was initially allowed for, to maximise profits. It was found that the offer being accepted prior to the designs being developed caused the quality of designs for construction to be of poor quality so that the tenderer could make a more significant profit. However, the results suggest that certain contractors had underpriced, hence forcing them to find ways of saving money to complete the work within the budget, at the cost of inferior quality.

The findings further reveal the prevalence of unethical behaviour resulting from poor scope definition in tender documents. The study cited various unethical behaviour instances (Harris and McCaffer, 2013; Phillips, 2012; Wang and Buckeridge, 2015). Most of these were made possible by the loopholes in the tender documents. Appointed contractors found ways to inflate dditional on-site work and increase rates and quantities. This led to loopholes for submitting exorbitant variations to the contract by the contractor's quantity surveyors. The results suggest that the quantity surveyors did not always prepare ethical and accurate rates and quantities in their calculations may be due to the contractor being paid by the contractor and no longer working in the interest of the client as their fees were based on a percentage of the contract value. Hence, the higher the contract value could be pushed, the higher the professionals' fees received from the contractor would be. The approval of variations such as these also suggests some unethical conduct due to the lack of correct calculations being brought to the attention of those in charge of documentation prior to their approval.

The findings revealed a risk of the consultant team being the judge and preparer of the contractor's claims, leading to unethical decisions to benefit the consortium team. In traditional contracts, the professional teams are appointed and paid separately from the client. These prepare all work in the client's best interest and according to how the contract allows. Another instance of unethical behaviour was the non-payment of subcontractors and consultants after the client had paid the consortium head. This disadvantaged the project's progress and resulted in additional expenditure from the client. Non-termination of non-performing appointments was also unethical as there was enough contractual obligation to issue defaulting parties warning letters for the reasonable cause of non-performance; however, no evidence of it ever being done was provided.

6 CONCLUSIONS AND RECOMMENDATIONS

The study concludes that challenges associated with tender documentation during contract management of public sector projects are affected by a lack of knowledge by those implementing procurement, and inefficiencies in the tender document which lead to cost and time overruns. In order to overcome shortcomings in the tender document, the public sector needs to appoint qualified personnel and train their existing employees accordingly. This will ensure that a higher standard of documentation is advertised for tender, which contains a site-specific scope in line with the client's requirements. This will reduce the number of variations and eliminate loopholes for unethical behaviour.

The study further recommends that a clear understanding of responsibilities should be set out between all role players and that the officials in the public sector should be given appropriate training on procurement management in construction. A clear strategy involving all stakeholders and role-players should ensure a fully consolidated scope is implemented from the onset. The tender should provide; enough site-specific information and quality of ground conditions. Furthermore, tendering procedures should be based on equity and policies to limit the existence of favouritism. Moreover, it is paramount that the tender process should involve the input of technical knowledgeable staff to ensure contractual clauses regarding insurance, payment, cancellation and penalties are included to minimise wasteful expenditure on projects.

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Infrastructure: Economic, social/environmental sustainability

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Non-motorized transport systems: Current and emerging themes globally – A bibliometric review

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ABSTRACT: Recently, there has been significant rise in the interest and application of non-motorized transport (NMT). However, there is very little that is known about the new forms and developments within NMT. Consequently, this paper investigated the current and emerging themes around NMT globally. A bibliometric review process of publications whereby the VOSViewer software was utilized to analyze relationships and emerging developments in NMT planning and management. The paper reviewed developments in NMT from 1996 to 2022. It revealed key authors, core themes, countries and organizations which have published in the field of NMT and the relationship between NMT and accessibility, safety, infrastructure and sustainability. This research brought forth the lack of NMT articles published for the last 26 years, key themes which have already been covered and the lack of government participation. More articles around NMT need to be published and the implementation of NMT policies, plans and projects.

Keywords: Non-motorized transport, accessibility, safety, infrastructure and sustainability

1 INTRODUCTION

The world's urban population in 2014 was 54% and is expected to increase to 66% by the year 2050 which will result in an amplified demand in motorized transportation due to urbanization expanding cities which would require smart growth (Mansoor et al. 2022: 1561). The amount of automobiles will then be expected to rise between 2.2-2.6 times around the world between 2014 to 2050, this will create congestion and air pollution (Mansoor et al. 2022: 1561). Cities around the world are trying to find ways in which they can reduce greenhouse gas emissions and human-induced climate change that leads extensive degradation and loss (Turner-Brady 2022: 1-8). Policy around the mitigation of climate change needs to take the forefront in planning projects and policies. A shift from motorized transportation to sustainable mobility needs to occur. Subsequently, non-motorized transport (NMT), is being promoted since it is transport that represents walking, cycling and many other options that are not motorized which overcome the shortcoming of motorized transportation. Hence, there is a renewed interest in aspects that would improve safety, accessibility, infrastructure, sustainability and public transport for NMT (Ladin et al. 2014).

The paper found that this is still a developing topic with only 165 papers written between 1996 and 2022. The paper sough to evaluate the key themes within these papers and identify

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gaps. In order to achieve this, a bibliometric analysis of keywords, key authors, countries, organizations and the number of publications and citations will inform key areas which have already been addressed giving way to diverse newer thoughts pertaining to NMT. Thereafter, the paper goes on to present an analysis of keywords on the relationship between NMT and safety, accessibility, infrastructure, sustainability and public transport. It ends by drawing on policy implications and recommendations.

2 DATA ACQUISITION

First data for the term “non-motorized transport” and the term “non-motorised transport” from the year 1996-2022 was exported from the Web of Science database. When exploring a number of databases, the Web of Science proved to have the widest range of publications for NMT and was compatible with the analysis system of choice (VOSViewer) to be used in this study. The next type of data that was exported from the Web of Science from 1996-2022 was the relationship of NMTs and accessibility, safety, infrastructure and sustainability respectively. It was then imported to VOSViewer for analysis.

3 BIBLIOMETRIC ANALYSIS

The data was imported to the VOSViewer system. Data for both “non-motorized transport” and “non-motorised transport” from the Web of Science between 1996-2022 were then combined when imported into VOSViewer for analysis.

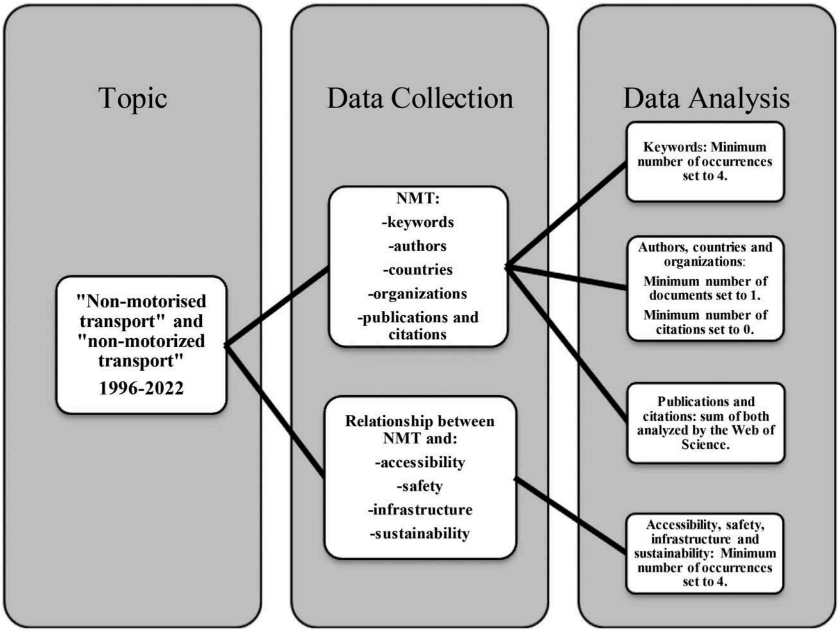


Figure 1. Breakdown of data analysis.
(Source: Authors 2022)

Data was then analyzed (Figure 1) in terms of keywords (network map), authors (table), countries (table), organizations (table) and date of publications and citations (bar and line graphs respectively combined). Data for NMT and its relationship with accessibility, safety, infrastructure and sustainability was then analyzed in terms of keywords for each theme's relationship with NMT to create network maps respectively. Data analysis took place using either a minimum number of 2 documents and 0 citations or a minimum number of 4 occurrences which can be seen above.

4 RESULTS AND DISCUSSION

The results below are a direct indication of the main themes, authors, organizations, countries, trends and relationships that have been identified when looking at articles around NMT between 1996-2022.

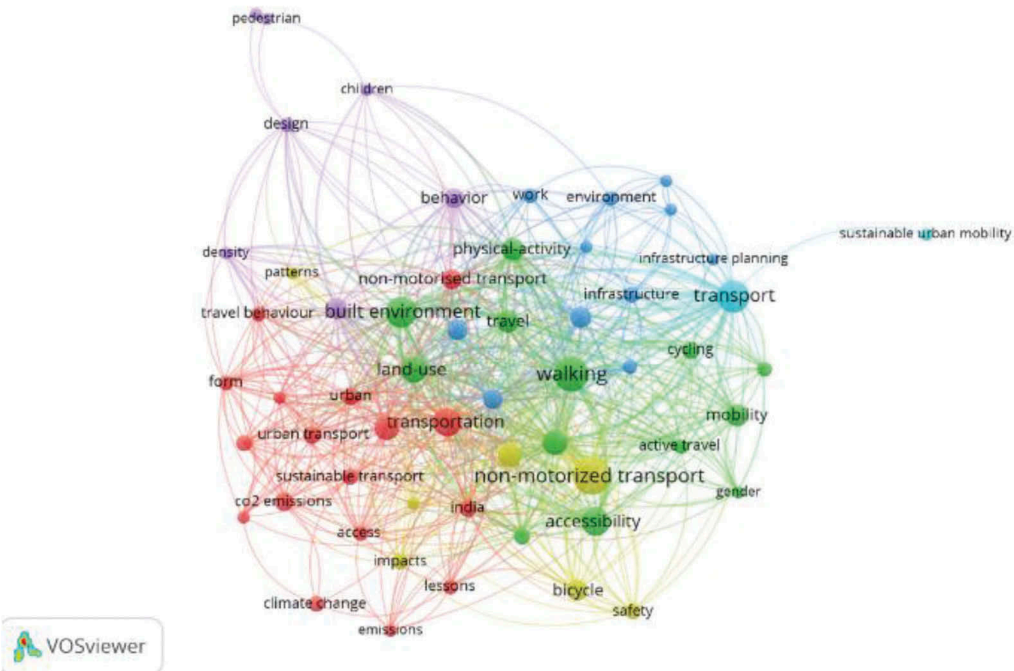


Figure 2. All key words on co-occurrence network map on NMTs based on number of occurrences. (Source: Authors 2022)

A co-occurrence analysis of published papers on NMTs between 1996-2022 was performed (Figure 2 and Table 1). Of the total 165 articles, and a total of 743 keywords, there were only 57 keywords that met the threshold. The resulting analysis was 6 clusters, 598 links and a total link strength of 1050.

The top 5 co-occurring keywords (Figure 2 and Table 1) in articles based on the number of co-occurrences are "non-motorized transport" with 37 occurrences; "walking" with 27 occurrences; "transport" with 24 occurrences; "built environment" with 22 occurrences, and "transportation" with 19 occurrences. The top 5 co-occurring keywords (Table 1) in articles based on total link strength are "walking" with a total link strength of 128; "built environment" with a total link strength of 127; "non-motorized transport" with a total link strength of 126; "transport" with total link strength of 93, and "land-use" with a total link strength of 87. "Non-motorized transport" has the highest number of occurrences but "walking" has the highest number of links and total link strength which implies that "walking" has the strongest relationship to NMTs despite not having the highest number of occurrences. "Built environment" has a lower number of occurrences than "non-motorized transport" and "transport"

Table 1. Top 5 key words on co-occurrence table on NMTs based on total link strength.

Based on co-occurrence				Based on total link strength			
Keywords	Occurrences	Links	Total Link Strength	Keywords	Occurrences	Links	Total Link Strength
Non-motorized transport	34	40	126	Walking	27	41	128
Walking	27	41	128	Built-environment	22	41	127
Transport	24	40	93	Non-motorized transport	34	40	126
Built-environment	22	41	127	Transport	24	40	93
Transportation	19	40	79	Land-use	16	38	87

(Source: Authors 2022)

but has a higher number of links and total link strength suggesting that "built environment" has a stronger relationship to NMTs despite having less occurrences.

An analysis of all authors from articles on NMTs between 1996-2022 based on the number of documents and citations was performed below (Table 2). Of the total 165 articles, and a total of 417 authors, there were only 27 authors that met the threshold.

Table 2. Top 5 authors on NMTs based on number of documents and citations.

Based on number of documents				Based on number of citations			
Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
Tiwari, Geetam	6	139	5	Pucher, J	2	337	0
Jain, Deepty	5	127	5	Rietveld, P	2	161	0
Verma, Ashish	5	69	4	Tiwari, Geetam	6	139	5
Hankey, Steve	4	42	5	Jain, Deepty	5	127	5
Rahul, T. M	4	55	4	Tiwari, G	2	95	0

(Source: Authors 2022).

The top 5 authors (Table 2) based on the number of documents in articles are "Tiwari, Geetam" with 6 documents; "Jain, Deepty" with 5 documents; "Verma, Ashish" with 5 documents; "Hankey, Steve" with 4 documents, and "Rahul, T. M" with 4 documents. The top 5 authors based on the number of citations in articles are "Pucher, J" with 337 citations; "Rietveld, J" with 161 citations; "Tiwari, Geetam" with 139 citations; "Jain, Deepty" with 127 citations, and "Tiwari, G" with 95 citations. "Tiwari, Geetam" has the highest number of documents and total link strength but only has the third highest number of citations. "Pucher, J" and "Rietveld, p" only have 2 documents yet have the highest and second highest number of citations respectively which indicates that the quality of the documents plays a larger role in citations over the quantity of documents.

An analysis of all countries (Table 3) from articles on NMTs between 1996-2022 based on the number of documents and citations was performed below. Of the total 165 articles, and a total of 50 countries, there were only 30 countries that met the threshold.

Table 3. Top 5 countries on NMTs based on number of documents and citations.

Based on number of documents				Based on number of citations			
Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
USA	32	1171	14	USA	32	1171	14
India	20	515	1	India	20	515	1
Peoples R China	15	376	11	England	10	416	7
Brazil	13	172	9	Peoples R China	15	376	11
England	10	416	7	Netherlands	8	364	4

(Source: Authors 2022)

The top 5 countries (Table 3) based on the number of documents in articles are "USA" with 32 documents; "India" with 20 documents; "Peoples R China" with 15 documents; "Brazil" with 13 documents, and "England" with 10 documents. The top 5 countries based on the number of citations in articles are "USA" with 1171 citations; "India" with 515 citations; "England" with 416 citations; "People R China" with 376 citations, and "Netherlands" with 364 citations. "USA" has the highest number of documents, citations and total link strength. "England" has the fifth highest number of documents, however, it has the third highest number of citations which suggest that these documents are more widely sought out.

An analysis of all organizations (Table 4) from articles on NMTs between 1996-2022 based on the number of documents and citations was performed below. Of the total 225 articles, and a total of 50 countries, there were only 41 countries that met the threshold.

Table 4. Top 5 organizations on NMTs based on number of documents and citations.

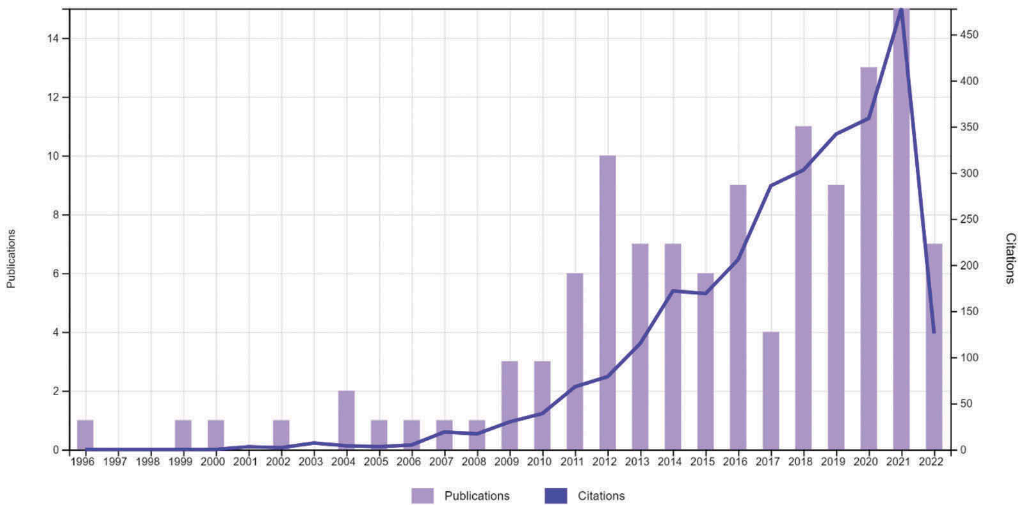
Based on number of documents				Based on number of citations			
Organization	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
University of Cape Town	7	103	0	Rutgers State University	3	345	2
Nanyang Technological University	6	45	0	Peking University	3	224	0
Universidade Federal do Rio de Janeiro	5	23	0	University of California Berkeley	2	181	2
Virginia Tech	4	42	2	Inst Transport Econ	2	167	0
Indian Institute of Technology Delhi	4	94	0	Free University Amsterdam	2	161	0

(Source: Authors 2022)

The top 5 organizations (Table 4) based on the number of documents in articles are “University of Cape Town” with 7 documents; “Nanyang Technological University” with 6 documents; “Universidade Federal do Rio de Janeiro” with 5 documents; “Virginia Techl” with 4 documents, and “Indian Institute of Technology Delhi” with 4 documents. The top 5 organizations based on the number of citations in articles are “Rutgers State University” with 345 citations; “Peking University” with 224 citations; “University of California Berkeley” with 181 citations; “Inst Transport Econ” with 167 citations, and “Free University Amsterdam” with 161 citations. “University of Cape Town” has the highest number of documents yet does not appear on the top five list of citations. All top five organizations which have the highest number of documents do not appear on the list of the top five number of citations list which “Rutgers State University” seems to be on top of. The number of documents does not correlate with the number of citations.

4.1 *Times cited and publications over time*

The two graphs below (Graph 1: “non-motorized transport” and Graph 2: “non-motorised transport”), both indicate article publications and citations between 1996-2022 that are centred around NMTs. “Non-motorised transport” (Graph 2) articles only began in 1999 whereas “non-motorized transport” (Graph 1) article/s were being published during 1996.



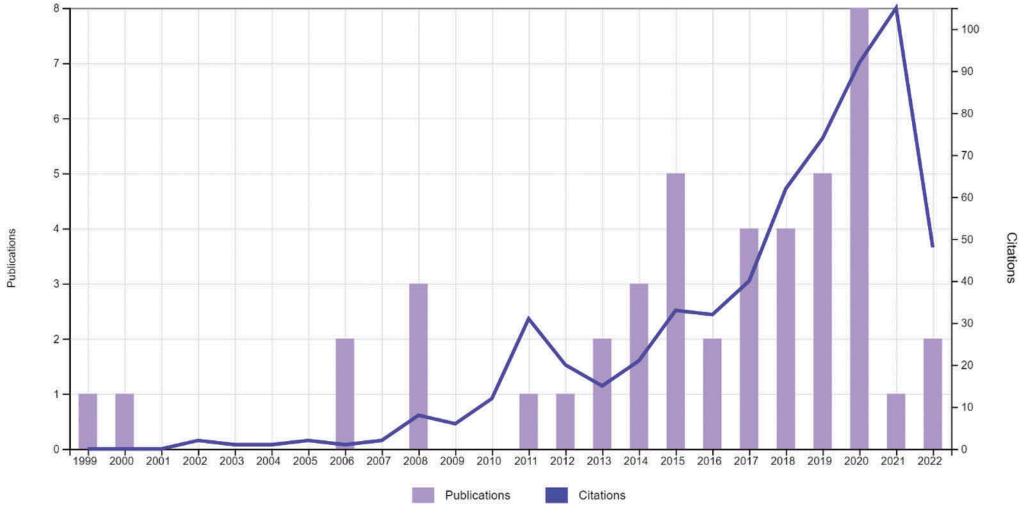
Graph 1. Non-motorized transport publications and citations between 1996-2022.
(Source: Authors 2022)

Between 1996-2010 there were a total of 0-5 articles being published each year. From the year 2011, a steady rise in the number of articles being published can be noted though they remain low. The year 2020 and 2021 saw the highest number combined publications and citations respectively. The year 2011 (Graph 2) saw a spike in the number of citations, although citations in both graphs seem to increase based on the number of articles published the previous year.

The combined number of articles and citations (Graph 1 and Graph 2) published per year have never exceeded 21 and 650 respectively.

4.2 *NMT and accessibility*

A co-occurrence analysis of all keywords from published papers on NMTs and accessibility between 1996-2022 based on occurrences was performed. Of the total 31 articles, and a total of 182 keywords, there were only 12 keywords that met the threshold. The resulting analysis



Graph 2. Non-motorised transport publications and citations between 1996-2022.
(Source: Authors 2022)

was 2 clusters, 58 links and a total link strength of 118. The top 5 co-occurring keywords in articles based on occurrences are "accessibility" with 18 occurrences; "land-use" with 8 occurrences; "non-motorized transport" with 8 occurrences; "walking" with 6 occurrences, and "built environment" with 6 occurrences. Accessibility to NMT is one of the most vital factors that needs to be taken into consideration. A study in Catania, Italy, indicates that land use and the built environment both play a major role in accessibility and NMT through effective land use planning minimizing motorized transport dependency and increasing NMT use. This leads to the reduction of transport energy dependence and climate change (Inturri et al 2017: 3277-3284). The importance of walking can be noted through a study conducted on the accessibility of NMT to retail activities in Zaragoza, Spain. It found that walking to retail stores was dependent on distance travelled and age of user. Users who were older (>65 years old) were less likely to walk as much as users who were younger (<65 years old), meaning that walking is one of the major themes researched under accessibility and NMT due to it possibly excluding certain users (Arranz-López et al 2019: 644-649).

4.3 *NMT and safety*

A co-occurrence analysis of all keywords (Figure 3) from published papers on NMTs between 1996-2022 based on occurrences was performed. Of the total 31 articles, and a total of 169 keywords, there were only 10 keywords that met the threshold. The resulting analysis was 3 clusters, 29 links and a total link strength of 63. Figure 3 below shows the top 5 co-occurring keywords in articles based on occurrences are "non-motorized transport" with 10 occurrences; "transportation" with 8 occurrences; "safety" with 6 occurrences; "physical-activity" with 5 occurrences, and "built environment" with 5 occurrences.

A study undertaken in China analysing both safety, physical activity, the built environment found that traffic safety may affect the number of people willing to use NMT due to the number of new drivers in Chinese cities (Day 2016: 313-315). Fear of crime also affects the number of people willing to participate in physical activity, as crime rates have increased in China since the last three decades due to market reform. The study suggests that the concept of *guanxi* which represents the network of personal bonds that shapes all fragments of life. Guanxi is related to safety and could be applied to remedy the situation between the built environment, safety and physical activity (Day 2016: 313-315).

Figure 3. All key words on co-occurrence network map on NMTs and infrastructure based on number of occurrences.

(Source: Authors 2022)

4.4 *NMT and infrastructure*

A co-occurrence analysis of all keywords (Figure 4) from published papers on NMTs and infrastructure between 1996-2022 based on occurrences was performed. Of the total 54 articles, and a total of 276 keywords, there were only 20 keywords that met the threshold. The resulting analysis was 5 clusters, 101 links and a total link strength of 154. Figure 4 below shows the top 5 co-occurring keywords in articles based on occurrences are "walking" with 11 occurrences; "non-motorized transport" with 11 occurrences; "land-use" with 7 occurrences; "cities" with 7 occurrences, and "transportation" with 7 occurrences.

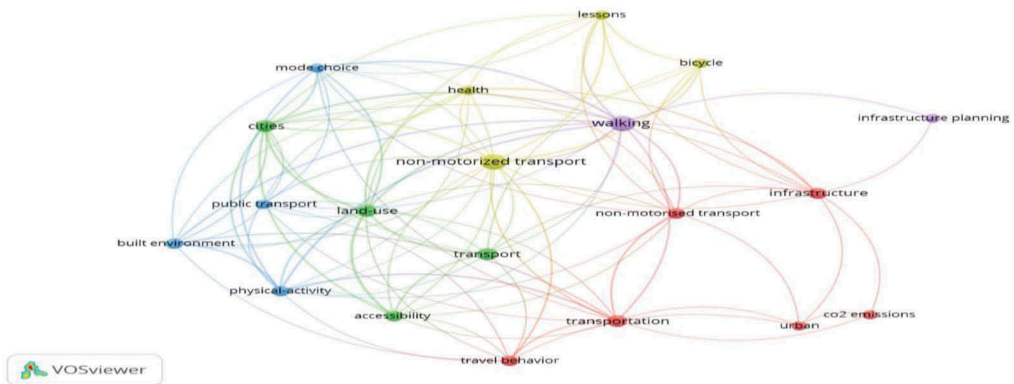


Figure 4. All key words on co-occurrence network map on NMTs and infrastructure based on number of occurrences.

(Source: Authors 2022)

A case study of two Indian cities, Rajkot and Vizag, looking at the relationship of NMT infrastructure and NMT use concluded that the improvement in NMT infrastructure leads to an increased use of NMT (walking and cycling) due to the reduction of risk to users (Tiwari, Jain and Rao 2016: 289-290). A study conducted in Minneapolis, United States of America, further reiterates that pedestrian traffic is linked to transportation infrastructure, land use, and neighbourhood characteristics (Hankey et al 2012: 315).

4.5 *NMT and sustainability*

A co-occurrence analysis of all keywords from published papers on NMTs between 1996-2022 based on occurrences was performed. Of the total 32 articles, and a total of 246 keywords, there were only 14 keywords that met the threshold. The resulting analysis was 3 clusters, 61 links and a total link strength of 94. Table 1 above shows the top 5 key words co-occurring in articles on NMTs based on occurrences. The top 5 co-occurring keywords in articles based on occurrences are "non-motorized transport" with 11 occurrences; "cities" with 7 occurrences; "walking" with 5 occurrences; "built environment" with 5 occurrences, and "sustainability" with 5 occurrences. A case study looking at Italian cities during the COVID-19 pandemic and their sustainable mobility was analyzed (Barbarossa 2020: 17). The study revealed that the cities temporarily reallocated road space in favour of sustainable mobility (walking and cycling) in alignment with social distancing and healthy active lifestyles. These temporary measure proved successful and can be used to implement new measures in line with it. This promotes sustainable mobility and the rethinking of how urban spaces are planned (Barbarossa 2020: 17).

5 POLICY IMPLICATIONS

Given the results and discussion, the amount of research carried out pertaining to NMT is quite scarce. The organisations behind the highest number of documents and citations suggest that the top 5 articles are from higher education institutions. This needs to change with articles that should be funded by governments instead to boost the number of publications and assist in implementing policies in support of NMT. Each emergent theme is supported by case studies that have been undertaken in cities around the world which means that there is enough evidence to implement policies which promote NMT. More policy around NMT assisting in the overall sustainability of cities needs to implemented as the relationship between NMT and sustainability proposes that main themes primarily look at the citywide level.

6 RECOMMENDATIONS AND CONCLUSION

More studies focused on NMT need to be carried out (as there were only 165 between 1996-2022) in both developed and developing countries to ensure that there are various case studies and evidence that can inform future projects, plans and policies which can promote a more efficient, safer, accessible and adequate infrastructure NMT. There is also a need for papers around the relationship between NMT and accessibility, safety, infrastructure and sustainability. Future papers need to analyse the deeper relationship of NMT to emergent themes and how governments can capitalise on the efficient implementation of NMT.

To conclude, the emergent themes based on the highest number of occurrences in all NMT articles were "non-motorized transport", "walking", "transport", "built environment" and "transportation" which suggest that all papers look at NMT as a form of transport but also relate it to mode choice (walking) and in terms of its relationship to a human-made environment (built environment). The key authors, organisations and countries all indicated that the number of documents produced did not correlate to the number of citations which suggests that citations rely on the quality of the article not the quantity. The year 2020 saw the highest number of NMT publications since 1996 but the year 2021 saw the highest number of citations which would suggest that there is a strong relationship between the number of publications and the number of citations. The relationship between NMT and accessibility, safety, infrastructure and sustainability was analyzed and the resulting emergent themes suggest that mode choice, land-use and the built environment are the most researched themes around NMT and the various terms. Each term had various case studies which corroborate with the results of the study. The results from this study have highlighted the gaps in NMT literature and promotes diverse NMT articles which will look further than mode choice, land-use and the built environment.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Effects of building envelope parameters on energy performance of high-rise commercial buildings

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ABSTRACT: Sustainable design is achievable based on the social, economic, and environment pillars that are interrelated with the major energy consumptions accruing worldwide. Saudi Arabia is one of the largest countries that consume massive energy to operate buildings due to the country's fast economic development and extremely hot weather. The researcher analyzed building envelope variables in an existing building in Riyadh, Saudi Arabia, and measured their effect on energy consumption based on ASHRAE 90.1-2019 and LEED guidelines. The researcher used REVIT for modeling and HAP for simulation as tools to conduct data. The researcher concluded that by altering wall thermal resistance, window thermal transmittance, solar heat gain coefficient, window visible transmittance, air infiltration/leakage, wall-to-window ratio, building orientation, and sun shading devices, the building envelope will save cumulatively 11.71% of energy consumption. The design guidelines presented in this research are recommended to enhance the building's energy performance and preserve nonrenewable energy

Keywords: Energy Consumption, Building Envelope, Modeling, Simulation, Saudi Arabia

1 INTRODUCTION

Sustainable building design attempts to reduce adverse consequences on the environment, health, and comfort of occupants through enhancing the building's performance (U.S. General Services Administration, 2021). Sustainable design and construction elements can be categorized into three pillars: environment, society, and economic. According to the Whole Building Design Guide (WBDG, 2021), the primary objectives of sustainable design are to reduce consumption of natural resources, eliminate pollution, and create healthy environments for building occupants. These design objectives have become points of interest globally.

Based on research by Susilawati and Al-Surf (2011), one of the countries that has demonstrated interest in sustainable design for the past few years and is a member of IPCC is the Kingdom of Saudi Arabia (KSA), a developing country dependent on non-renewable resources, such as oil and gas, for the majority of their financial resources.

Belloumi and Alshehry (2016) said rapid urbanization in Saudi Arabia and inexpensive energy resources availability have resulted in numerous tall buildings with semi-transparent to fully glazed facades. Although a glazed façade on a building adds aesthetic design and allows great daylight into the building, this design triggers other issues: their negative impact on the building energy consumption towards cooling the building and achieving thermal comfort for occupants. The default approach in such structures is to turn on the air conditioning (A/C) unit to overcome the heat gain coming from the windows, which leads to higher electrical bills

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and the waste of renewable energy (Saied Al Surf et al., 2013). Therefore, sustainable design in general and in the building envelope specifically was endorsed. It is essential not only because of thermal comfort and energy conservation implications, but also because it helps sustain precious natural resources. In this paper, the researcher objectives were to analyze the factors in building envelope systems that impact energy consumption in commercial high-rise buildings, and to develop recommendations for the optimal design and material selection to minimize energy consumption in Saudi Arabia.

1.1 *Research problem*

In recent years, a substantial amount of building development has occurred throughout the KSA. Unfortunately, many buildings have been constructed with little or no concern of the extreme hot weather, which allows outside air to penetrate the building and increase the cooling load and energy consumption (Al-Qahtani & Elgizawi, 2020). A/C systems in buildings in Saudi Arabia are responsible for about 70% of the energy consumption, whereas the energy used for A/C in the United Kingdom and the United States is 22% and 21% respectively (Saudi Energy Efficiency Center, 2013).

2 LITERATURE REVIEW

2.1 *Climate responsive design*

Climate change is one of the most significant challenges human civilization encounters in the 21st century. Carbon dioxide emissions can be reduced by improving how buildings are designed, constructed, maintained, and used to tackle climate change (Khan, 2021). Climate-responsive architecture is a design practice that focuses on creating structures that serve side by side with the local climate, not despite it. Climate-responsive architecture seeks to create sustainable and optimized building designs by contemplating the weather conditions in the specific area where the building is constructed (Malekafzali, 2017).

According to Encyclopedia (2018), the climate in Saudi Arabia is arid and very hot; dust storms and sandstorms are common. Day and night temperatures fluctuate significantly. From May to September, the hottest period, daytime temperatures reach 129°F. From October through April months, the climate is more moderate, with evening temperatures between 61°F and 70°F.

Alrashed and Asif (2015) identified six climatic zones in Saudi Arabia: The sixth climatic zone is Al-Ruba Al-Khali, which is not inhabited, and there are no weather data measurements in this zone. The climate of zone 1can be identified as subtropical with a Mediterranean subzone and a mountainous subtype. The climate of zone 2 can be identified as hot and dry with a maritime desert subzone. The climate of zone 3 can be identified as a hot and dry maritime subzone while the climate of zone 4 is identified as cold and dry with a desert subzone, and zone 5 is identified as hot and dry with a desert subzone.

Designing climate-responsive buildings in Saudi Arabia is challenging, requiring an understanding of building materials and how buildings are designed, constructed, and operated. The process becomes more difficult with increasing thermal comfort expectations. Alaidroos and Krarti (2015) explained that climate-responsive architecture and sustainable strategies are ideal for achieving thermal comfort in buildings without employing significant energy for cooling or heating. In hot climates, such as in Saudi Arabia, the efficiency of the cooling systems has a significant impact on the total energy consumption and thermal comfort. The less efficient a cooling system is, the more energy it will use, thus, resulting in a significant increase in natural resources utilization and environmental pollution.

2.2 *Building envelope*

The building envelope is defined as the exterior building structure, and it is composed of opaque elements and fenestration systems. Opaque components include walls, roofs, slabs, and the basement. Fenestration systems include windows, skylights, and doors (Dinapradipta, 2015). The building envelope protects the building's interiors and inhabitants from the climate circumstances and buffers them from other external factors. Each part of the building envelope bears different challenges, but they need to accomplish the same energy conservation and sustainability (Lau et al., 2014). According to WBDG (2021), buildings must be designed and worked as an integrated structure rather than a separated collection of parts. Thus, the selection of building envelope materials should incorporate with the entire building. Builders and manufacturers need to consider collaborating with architects and designers to select suitable building envelope components to create energy-efficient buildings and enhance building performance

2.3 *Saudi Arabia energy consumption*

Said and Al Omran (2015) explained that although Saudi Arabia is the largest oil exporter, previous studies have explained that Saudi Arabia could be a net oil importer by 2030 or 2038 due to the consequence of extreme national oil consumption. The annual rate of growth of energy consumption continues to increase mainly due to the increase in population, with an annual growth rate of 1.54%. Therefore, the volume of construction work in the country is dramatically increasing, posing challenges in energy demand and the environment. Alrashed and Asif (2015) showed that the building construction sector in Saudi Arabia is the largest and fastest in the Gulf Cooperation Council (GCC) states. It is estimated that 2.32 million new buildings are to be built by 2020 to meet the growing population's demand.

2.4 *Saudi Arabia 2030 vision towards sustainability*

U.S. Energy Information Administration (2021) explained that energy efficiency was initially overlooked by the Saudi government since energy consumption was low and no serious threat from peak loads was expected. Nonetheless, due to the rapid economic growth and population increase, there was a sharp expansion in KSA electricity consumption from both the building and industrial sectors. The lack of energy efficiency standards and regulations has made the rise in KSA energy consumption even more critical in the last decade.

The deputy crown prince, Mohammed bin Salman, son of the King of Saudi Arabia, has set a plan to save the Saudi economy by 2030. The plan is called Saudi Vision 2030. Saudi Gazette (2016) defined Vision 2030 as a strategic framework to decrease Saudi Arabia's reliance on oil, diversify its economy, and create public service sectors, such as health, education, and infrastructure.

Complying with sustainable design standards at each phase in building construction will decrease adverse environmental influences, increase occupants' health, and help save money which align with Saudi 2030 Vision. According to Abdul Ghafour (2014) adopting sustainable design and adequately designing building envelopes could save up to 60% of electricity, save 40 GW/hour every year, and reduce the electricity bill by at least two billion Saudi Riyals annually, which is equivalent to approximately 530 million U.S. dollars.

2.5 *Building simulation*

Buildings consume more than one-third of the world's primary energy (Hong et al., 2018). Decreasing energy usage and greenhouse gas emissions in buildings through energy preservation is considered an essential strategy for achieving sustainable design. Energy consumption does not depend on the individual performance of envelope components and mechanical systems; however, it considers their overall performance as an integrated system within the building and its relationship with the environment (U.S. Department of Energy, 2015). This complicated and iterative interactions must be modeled and simulated for comprehensive energy performance analysis. Building simulation serves not only to explain the interactions between the building and its occupants, HVAC systems, and the outdoor climate, but also to make proper environmentally-friendly design decisions (Clarke & Hensen, 2015).

3 METHODOLOGY

Adopting a quasi-experimental research methodology, the researcher modeled and simulated an existing building in Riyadh, Saudi Arabia, to evaluate the building's energy performance. The simulation of the current building design created baseline data to base a comparison on energy consumption after changing the independent variables. The energy efficiency target was set to comply with ASHRAE 90.1-2019 building codes.This research aimed to analyze the effect of the building envelope design parameters on energy consumption and develop optimized design solutions that exceed the prerequisite standard and gain credits according to the optimize energy performance rating in LEED V4.1.

3.1 *Research design*

In this study, the researcher digitally modeled and simulated the Olaya building in Riyadh, Saudi Arabia, during July, the hottest month, of 2021. The case study building served as the one-group study. The researcher performed a pre-intervention simulation where the independent variables were not altered. This step concluded a baseline of the existing condition of the independent variables in the building. Then, the researcher performed an intervention where the variables were modified, one variable at a time, during July, the hottest month, in the year 2021. Then, a simulation was done after the intervention to test the effect of the independent variable (i.e., building envelope parameters) modifications on the dependent variable (i.e., energy performance). Throughout these steps, the researcher evaluated the impact of building envelope parameters on energy performance, which enabled the researcher to provide suitable design suggestions to minimize energy consumption and cooling loads.

3.2 *Research variable*

The independent variables included: Wall thermal resistance (R-value), Windows thermal transmittance (U-value), Solar heat gain coefficient (SHGC), Window Visible Transmittance (VT), Air infiltration/leakage, Window-to-Wall ratio (WWR), Building orientation, Sun-shading devices. The dependent variable was the energy consumption

3.3 *Validation*

Internal validity was high because the building envelope parameters tested in this study have been identified in most building rating systems, such as the ASHREA 90.1 and the National Fenestration Rating Council (NFRC), and mentioned in previous building performance analytical research. The experiment was based on digitally modeling a building in Saudi Arabia and simulating the weather conditions and energy consumption. Therefore, all the threats to internal validity were not applicable. On the other hand, external validity was low because the case study sample was a stratified purposive sample, and the results could be generalized to the commercial buildings in the central region of Saudi Arabia only where the building materials and construction specifications are the same of the case study in the research

3.4 *Case study*

The building was the Olaya towers, located at the junction of Olaya and Tahlia streets, which is considered part of the Golden Area Central Business District (CBD) in Riyadh City. The researcher collected basic information about the building construction and material specifications from the construction document obtained from the building contractors shown in Table 1.

Table 1. Olaya tower a basic building information.

Characteristics	Description
Address	3074 Olaya - al Olaya, Riyadh Saudi Arabia
Building Type	Skyscraper
Building Status	Existing – completed in 2013
Main Usage	Commercial office spaces.
Orientation	Front elevation facing northeast
Building Dimensions	147-6” L x 115-8” W x 590′ H
Number Of Stories	Above ground: 36, Below ground: 4 (parking garage)
Structural Material	Concrete
Facade Material	Glass/spandrel panels
Facade System	Curtain wall
Window Area	%60
Type Of Glass	Double pane – blue tint – reflective glass
Occupancy	4752 people, at 132 per floor
Operation Hours	24/5 – except national holidays
HVAC System	VAV
Fixture type	recessed unvented 0.84 w/ft2
Energy charge	0.069$/kw

3.4.1 *Modeling in Revit*

The construction document of the Olaya Tower A was obtained from the contractors; however, the researcher had to simplify the building drawings for this research a shown in Figure 1 . The building is homogeneous in its structure and materials; therefore, the researcher decided to focus on modeling one floor from the 36 floors. Floor 30 was chosen to be modeled using Revit because it is in the higher level of the building, and it would not be affected by the shadows/glare of the adjacent buildings during the simulating process.

The next step was to create thermal zones. Hong et al. (2000) explained that since building HVAC systems are often too complex to address the conditions of each room during the design stage, simplifications are often applied to the design of the HVAC systems. For

Figure 1. Olaya Tower A.

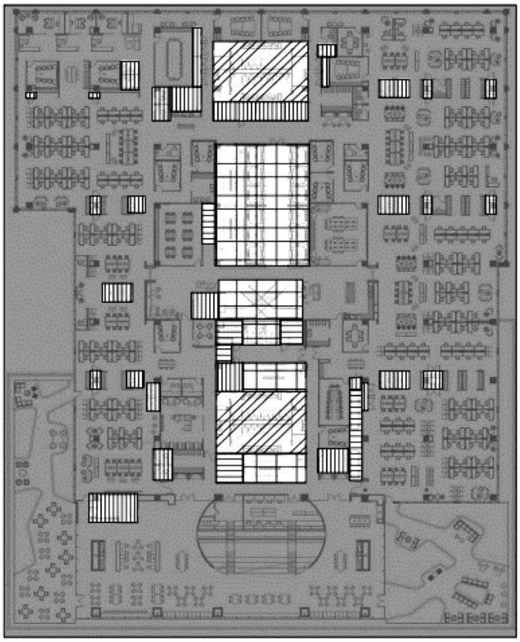

Figure 2. Zoning plan. The grey zone is the office area.

example, a real building may have many floors with different thermal conditions, or some rooms may have irregular shapes. In such cases, the researcher had to simplify the actual building into selected zones. The number of zones should not be too large, otherwise the calculating time would be quite long.

It is advisable to select a zone that is most heavily used for simulation and to generalize the result to other occupied zones in the building. In the model, there were five main zones: the main office area, the elevators, the restrooms, the mechanical rooms, and storage rooms as shown in Figure 2. The main office area was the researcher's concern because it is where most the energy is consumed by employees.

Creating zones was essential to separate operational spaces of the building required for energy simulation in HAP. Without creating zones in Revit architecture, energy of the building's various spaces cannot be modeled. In fact, the file cannot be exported to HAP software. After specifying zones, the researcher exported the model to Green Building XML (gbXML), and to HAP software to perform the energy analysis. By using gbXML format, the building's specifications defined in Revit were all exported to HAP.

3.4.2 *Weather simulation*

Weather is a major factor in energy consumption, and since there are six climate zones in Saudi Arabia, it was crucial to identify the climate in Riyadh where the case study is located. Riyadh is in zone 5, which is identified as hot and dry with a desert subzone. The researcher entered the information into HAP to generate a comprehensive weather report as shown in Table 2.

Table 2. Location parameter.

City Name	Riyadh
Location	Saudi Arabia
Latitude	24.7 Deg.
Longitude	-46.7 Deg.
Elevation	2007.0 ft
Summer Design Dry-Bulb	111.0 °F
Summer Coincident Wet-Bulb	64.0 °F
Summer Daily Range	25.2 °F
Winter Design Dry-Bulb	41.0 °F
Winter Design Wet-Bulb	34.2 °F
Atmospheric Clearness Number	1.00
Average Ground Reflectance	0.20
Local Time Zone (GMT +/- N hours)	-3.0 hours
Consider Daylight Savings Time	No

Throughout the year of 2021, the weather simulation showed that July 28 had the highest temperature values, with a high temperature that reached almost 115°F at 3:00pm and a low temperature of 77.4°F at 6:00 am.

3.4.3 *Energy simulation at baseline*

Establishing a baseline energy consumption was a fundamental step in order to compare the energy consumption and cooling loads while changing the independent variables. The goal was to achieve a higher saving percentage that would make the building eligible for LEED points.

Since July 28, 2022, was considered the hottest day throughout the year of 2022, the cooling load for different equipment types were also the highest. The precool coil load reached its peak on July 28, which is almost identical to the precool equipment load. This is to be expected since the temperature is high, and more energy is needed for cooling.

Results and Data Analysis

3.5 *R-value*

The baseline wall structure was a heavy wall with R- value of 8.93. Tables 3 and 4 compare the baseline and three different wall assemblies with three different R-values to understand how altering this variable affects energy consumption. The researcher introduced three wall structure options to compare with the baseline as shown in Table 3.

Table 3. Alternative options for wall structure R-values.

Alternative Options	R-value	Baseline	Simulating	Saving
1. Light weight wall	21.03	1,075,725	1073451	%0.22
2. Very light weight wall	11.02	1,075,725	1075177	%0.06
3. Brick face + insulation board	16.81	1,075,725	1073903	%0.17

The researcher found pout that option 1, the light weight wall, was the best option in saving 0.22% of the energy consumption comparing the baseline.

3.6 *Window U-value, SHGC, VT*

The windows in the baseline structure is a double-pane green low-E with a U-value of 0.42, SHGC of 0.25 and VT of 0.488. The researcher tested three different window structures to understand how altering these variables affects energy consumption as shown in Table 4.

Table 4. Alternative options for window assembly.

Alternative Options	U-Value	SHGC	VT	Baseline	Simulating	Saving
1. Blue/Grn Reflective	0.37	0.29	0.488	1,075,725	1067170	0.8%
2. Grey reflective w/ Argon	0.39	0.23	0.309	1,075,725	1,056,562	1.8%
3. Blue/Grn Reflective w/ Argon	0.304	0.30	0.28	1,075,725	1,059,576	1.78%

The researcher concluded that option 2, Gray reflective glass with ½ argon gas, was the best option in saving 1.8% of the energy consumption comparing the baseline.

3.7 *Air infiltration*

The baseline is at 0.3 ACH regarding air infiltration, which is the minimum value to meet the NFRC guidelines the researcher tested 4 options of air infiltration to understand how altering this variable affects energy consumption as shown in Table 5.

Table 5. Alternative options for building air infiltration.

Alternative Options	Air infiltration	Baseline	Simulating	Saving
Option 1	0.25	1,075,725	1067386	0.8%
Option 2	0.2	1,075,725	1068674	0.7%
Option 3	0.15	1,075,725	1069992	0.54%
Option 4	0.1	1,075,725	1071342	0.41%

The researcher concluded that option, 1: 0.25 ACH building infiltration, was the best option for saving 038% of energy consumption comparing the baseline.

3.8 *Window-to-Wall Ration (WWR)*

In regard to WWR, the baseline was 60%. It is worth mentioning that the wall includes the opaque wall and the spandrel panels. The researcher simulated three different options for the WWR to understand how altering this variable affects energy consumption as shown in Table 6.

Table 6. Alternative options for window-wall ratio.

Alternative Options	WWR	Baseline	Simulating	Saving
Option 1	50	1,075,725	1035879	3.7%
Option 2	40	1,075,725	1,034,808	3.8%
Option 3	24	1,075,725	1,014,592	5.6%

The researcher concluded that option 3: WWR of 24% is the best option in saving 5.6% of energy consumption comparing the baseline.

3.9 *Building orientation*

The current orientation of the building is at 24° north, 46° east, which was represented as the baseline orientation for this simulation. The researcher compare the baseline with three different building orientations to understand how rotation the building this variable affects energy consumption as shown in Table 7.

Table 7. Alternative options for building orientations.

Alternative Options	Rotation	Baseline	Simulating	Saving
Option 1	90	1,075,725	1071205	0.42%
Option 2	180	1,075,725	1,075,587	0.02%
Option 3	270	1,075,725	1,065,638	0.94%

The researcher established that rotating the building 270° from baseline was the best option for saving 4.2% of energy consumption comparing the baseline.

3.10 *Exterior sunshade devices*

The baseline did not have any exterior sunshade devices. The researcher added with three different overhang louver options to understand how altering this variable affects energy consumption as shown in Table 8.

Table 8. Alternative options for exterior sunshade devises.

Alternative Options	*Sunshade	Baseline	Simulating	Saving
Option 1	3” overhang	1,075,725	1074247	0.13%
Option 2	6” overhang	1,075,725	1071230	0.41%
Option 3	8” overhang	1,075,725	169733	0.55%

* The louvers overhang depth what were under the evaluations

The researcher concluded that Option 3 was the best option in saving 0.55% of the energy consumption comparing the baseline.

4 CONCLUSION

It is necessary to study climate-responsive strategies to optimize the building envelope performance to respond to arid conditions in Saudi Arabia. Manu et al. (2019) mentioned that installing air conditioners in an inadequately designed building is unfortunately more convenient than constructing an energy-efficient building, however this behavior raises the building operation cost and drain non-renewable resources. Presenting sustainable design alternative approaches aligned with the literature that Alaidroos and Krarti (2015) represented about the importance of climate-responsive architecture and sustainable strategies in achieving thermal comfort in buildings without employing significant energy for cooling or heating.

It had been proven in this research that building envelop, which includes opaque and fenestration, play a significant role in energy consumption and building energy performance. The researcher conducted by simulating an existing building in Riyadh, Saudi Arabia that using lightweight concrete with an R-value of 21.38 for the building opaque, a fenestration system of blue/green reflective triple-pane glass with 1/2 Argon gas with U-value of 0.37, SHGC of 0.29, and VT of 0.488, increasing insulation to tighten the building with 0.25 ACH, rotating the building 270°, minimizing the WWR to 24, and adding an exterior sunshade device of 8” deep overhang louvers will cumulatively save the building 11.71% of energy consumption.

These saving projections line up with Energy Star (2021) findings that stated that a well-designed building envelope, can make a real difference in utility bills where it saves up to 22% of energy consumption cost each year: 10% average savings generated from well-constructed walls and 12% average savings are from well insulated windows. Conservation energy is the core of the Saudi vision 2030 and the country’s road to sustainability.

The findings of this research are significant to scholars and architects who strive for optimal building envelope strategies and design innovations to meet or exceed the ASHRAE 90.1 standards. Building stakeholders in Saudi Arabia will also benefit from the findings of this research because it presents the potential for saving money on cooling despite the nearly year-round extremely hot climate. The energy-efficient solutions presented will eventually pay for themselves by lowering cooling costs, sustaining energy, and enhancing the building’s performance. Building occupants will be the greatest beneficiaries of these research findings because they spend 75% of their time indoors. The conducted design guidelines will increase thermal comfort and reduce unwanted heat in the building during the arid climate in Saudi Arabia. Per ASHRAE 55, thermal comfort enhances productivity and positively impacts occupants’ health and welfare.

This study prompts more research venues in sustainable design and energy performance. Future topics are to compare building envelope parameters in Saudi Arabia with building envelope parameters in the United States using similar climatic zones and temperatures, such as Arizona or Texas. Learning the similarities and differences between both countries’ structure materials and building codes would be remarkable. Moreover, studying the life cycle costs of buildings and assessing when to break even while investing upfront in sustainable design and products will be another future research potential to understand the value of sustainable design.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Risk factors in the selection of contractors' insurance options in the Ghana construction industry

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ABSTRACT: Insurance in the construction industry involves swapping or transferring a contingent claim for a definite amount to protect the interests of the stakeholders undertaking a construction project as a primary way of handling risks. This research aimed at assessing risk factors in the selection of contractor insurance options in the construction industry. The literature review was undertaken to identify risk factors associated with contractor insurance provision and select contractor insurance options. A quantitative research method was adopted, utilizing a structured questionnaires to elicit empirical data from contractors, consultants and insurance officers in Kumasi. The findings showed that exchange; rate fluctuation, unrealistic contract duration, inaccurate estimating, interference from clients, mistakes in design documents, inadequate contractor experience and materials damage were the most significant risk factors in construction projects. The study recommended that insurance provisions could assist contractors to proactively manage the construction risk and other risk factors associated with construction sector.

1 INTRODUCTION

In the construction industry, there is a potentiality that project risk prevention would fails, which brings about the need for insurance as an effective mechanism of a project risk mitigation and management (Akinradewo *et al.,* 2020). Debela (2018) states that risk management is regarded as a best practice in the management of construction projects. Thus, in a situation where the identified project risks cannot control through a transfer of risk to someone else through an indemnification clause, then it is significantly important to manage that risk through insurance (Debela, 2018). Insurance in the construction industry involves the swapping or transfer of a contingent claim for a definite amount in order to protect the interests of the stakeholders undertaking a construction project. Construction insurance is a primary way of handling risks that occur in the construction industry (Rendell and Yablonsky, 2003).

According to Akinradewo *et al.* (2020) there are different types of insurance options that are applicable to construction projects, which are mainly issues of bonds and guarantees

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utilised by clients to transfer contractors' risk of failure or poor performance to insurers. Its principal purpose is to transmit risks from subcontractors, main contractors, clients and stakeholders who are involved in construction to insurance firms so as to offer contingent money in difficult times. Construction insurance is essential in ensuring the accomplishment of construction projects with the insurers splitting loss which comes about due to contingencies and other adversities (Guilin *et al.,* 2004; Hillson, 2004). Project insurance also referred to as wrap-up is a broad insurance available for construction projects (Wang *et al.,* 2004). Project insurance is unlike traditional insurance whereby respective contractors provide their own insurance cover. It enables contractors or clients to acquire an insurance policy that covers almost every party involved in a construction venture. In the long run, especially big projects, more detailed project insurances may cover every party with gap-free cover (Heidenhain, 2001). Insurance is important and hence there exists the need to establish a framework for selection of contractor insurance options. The construction industry and its stakeholders are extensively associated with a great extent risk. This is because of the characteristic and nature of construction events, procedures, surroundings and entire organization. This research therefore seeks to identify risk factors associated with contractor insurance provision in the construction industry of Ghana.

2 LITERATURE REVIEW

2.1 *Underlying risk factors associated with contractor insurance provision*

Success on a construction project is hugely depends on how effectively and efficiently of project risk response and treatment techniques adopted and managed (Akinradewo et al., 2020). According to Baartz and Longley (2003), the risks that contractors face include poor site conditions, unfavorable weather, insufficient drawing details, delay in gaining access to site, failure of subcontractors to perform, lazy labor force, strikes, defects in construction, penalties, damages, late delivery of materials, costs arising from delayed completion of works (Baartz and Longley, 2003; Palmer et al., 1996). Risk is inherent in all construction projects, and it cannot totally eradicated. However, construction risk can be managed effectively in order to limit and mitigate the impacts on expected project outcomes (Mbachu and Taylor, 2014). Risks in construction are normally very complicated, dangerous, difficult to ascertain, price and mitigate. Risks necessitate insurers to give off the best quality of insurance service with the aid of research, training, updated engineering skills and good information technology (Heidenhain, 2001). In spite of these, it is not every underwriter that likes construction more especially the policy of contractors' all risks. Risks could be insurable like theft, fire or physical risks. Some risks have the capability of being transferred to suppliers or subcontractors. These risks include workmanship and quality of the materials. Other risks like bureaucratic delays could be shared with the client (Palmer et al., 1996).

According to Jarkas and Haupt (2014) construction risk factors in Thailand construction industry are mostly emanates from issues such as unavailability of funds; construction delay; financial failure of contractor; unclear scope of work; economic crisis; delay in solving contractual issues; delay in solving disputes; third-party delays; subcontractor failure; and subcontractor lack of adequate number of staff. Risk management is therefore a process of decision making for contractors. According to Edwards (1995), a promoter (client/financier) has the concern that a good rate of return is gotten for all risks which have been undertaken. The promoter is also concerned about how anticipated changes in costs estimated, timing and benefits will have an effect on rate of return (Edwards, 1995). The conventional view is that the farther risks are transferred from clients, the more secure and safer client's budget will be (Boothroyd and Emmett, 1996). This should however be balanced with the whole cost of transferring risk.

In a study by Palmer et al. (1996) and Baartz and Longley (2003), it was intimated that clients face a myriad of risks. These include failure in making payments for progressive works, failure in funding, additional administration and government costs, risks in land acquisition, materials not being available and delays in project (Palmer et al., 1996). The risk challenges may lead to problems of faulty construction projects and intermittent repairs, escalating costs, abandonment of project and waste in investment (Baartz and Longley, 2003). According to Boothroyd and Emmett (1996), a contractor must be adequately and sufficiently compensated for any risks which he takes responsibility for. This serves as the most cost efficient path for the client from the standpoint of the insurer. Conventionally, the motivation for insuring works is to achieve satisfaction for the client mainly by using an insurance policy like the contractors' all risk form of insurance (Boothroyd and Emmett, 1996).

2.2 *Special risk considerations: Contractors' perspectives*

Construction insurance encompasses all contracts of indemnity within the construction and its related activities where insurance is chosen as the medium through which liabilities are shifted and managed (Debela, 2018). Construction insurance is used as a collective term to describe various types of policies to protect construction works, erection and operation of machinery. Traditionally it is assumed to be only limited to the construction stage. However, the project is a whole life process, which includes a feasibility study, a call for tender and evaluation of tenders, an award of contract, construction and erection phases, a take-over and maintenance period. Many researchers (Hickson, 1987, Levine, 1991, Palmer et al., 1996, Advanced Study Group No, 1999, Bunni, 2003) discussed all possible insurance policies during the whole project process to build an overall picture of construction insurance. With the development of construction management and civil engineering, construction insurance products and services have become increasingly specialized since the first Contractors' All Risks policy was issued in 1929 to cover the construction of Lambeth Bridge over the Thames in London. A special policy was created in Germany in 1934 and started to spread slowly (Wassmer, 1998). Latent defects insurance was introduced as Decennial Insurance by French insurers during the 1980s. Insurance, which are generally required in connection with a construction project, can be divided into two basic categories: property insurance and liability insurance.

Recently, it has been extended to cover business interruption during construction process, which is generally termed as Delay in Start-up (DSU) or Advance Loss of Profit (ALOP). Although it would seem ideal to obtain one insurance policy covering a construction contract, this is not possible because the range of contract risks is vast and insurers specialize in underwriting certain risks (Levine, 1991). Project insurance, sometimes called wrap-up, is an all-embracing insurance for construction projects. Unlike conventional construction insurance coverage where each contractor provides his or her own insurance coverage, project insurance allows the client or contractor of the construction project to purchase an insurance policy covering most parties participating in a given project. It can best represent and protect client's interests, avoid an insurance gap and possibly save on project costs. In the long term, particularly for large projects, more specific project insurances can cover all parties with comprehensive non-duplicating, gap-free cover (Edwards et al., 1996). However, it has some limitations. For example, size is an important prerequisite and dominant factor in determining a project's suitability for project insurance. So a project must be sufficiently large, or at least contain significant labor costs, to make project insurance financially viable. Otherwise, the additional administrative cost generally makes it less worthwhile to use project insurance.

3 RESEARCH METHOD

The study used a quantitative research design. The targeted population consisted of D1 contractors, consultants and insurance personnel in Ghana. Purposive and snowball sampling techniques were employed. The purposive sampling technique was chosen because it allowed the researcher to find people with the right information and who were willing to provide answers on the topic being researched. Purposive sampling is a non-probability sampling technique that involves the deliberate selection of objects and subjects for the study. Snowball sampling technique also led to one respondent directing the researcher to respondents with similar characteristics being looked for. This was done until a representative sample size of seventy (70) was obtained. Seventy (70) questionnaires were sent out to the respondents and fifty-nine (59) questionnaires representing eighty-four (84) percent were retrieved. The high response rate of eighty-four (84) percent because of persistent follow ups on the respondents.

The statistical methods which were used in analyzing the data were frequencies and descriptive statistics. The descriptive statistics is the analytical tool for presenting data. Descriptive statistics comprises of methods for summarizing and presenting data. The descriptive statistics in the analysis of data helps for easy comprehension of huge amounts of data; and provides chance to correspond the research results to people. Furthermore, detailed analysis was conducted on the specific objectives using Relative Importance Index (RII). The RII values and mean aided in ranking the phenomena in terms of their importance by using index weights. W represented the weighting assigned to each factor by respondents, A represented the highest weighting (i.e. 5) while N represents the total number of respondents. Analysis of Variance (ANOVA) was used to test the significance in perception among the categories of respondents.

4 RESULTS AND DISCUSSION

4.1 *Category of research respondents*

Respondents were asked to indicate which category they belonged to. From Figure 1 below, twenty (20%) percent of respondents were in insurance firms. Fifty-three (53%) percent of respondents were contractors. The remaining twenty-seven (27%) percent were consultants. Majority of the respondents for this study are contractors. It is also indicated that the study has a fusion of different professionals in contractor insurance provision and this is good for the study.

Figure 1. Category of research respondents.

4.2 *Underlying risk factors associated with contractor insurance provision in the construction industry*

In this section, respondents were asked to rank the underlying risk factors associated with contractor insurance provision in the construction industry. Relative Importance Index (RII) analytical tool was used to rank the risk factors. Table 1 below shows the responses of the respondents. Exchange rate fluctuation placed first (1st) with mean of 4.24 and Relative Importance Index of 0.850. Unrealistic contract duration placed second (2nd) with mean of 4.13 and Relative Importance Index of 0.826. Inaccurate estimating placed third (3rd) with mean of 3.96 and Relative Importance Index of 0.792. Interference from client placed fourth (4th) with mean of 3.93 and Relative Importance Index of 0.786. Mistakes in design documents placed fifth (5th) with mean of 3.91 and Relative Importance Index of 0.781. Inadequate contractor experience placed sixth (6th) with mean of 3.70 and Relative Importance Index of 0.738. Materials damage placed seventh (7th) with mean of 3.52 and Relative Importance Index of 0.705.

According to literature, there are risks involved in undertaking construction projects (Akinradewo *et al.,* 2020; Baartz and Longley, 2003; Palmer et al., 1996). Exchange rate fluctuation is a risk that is predominant in construction projects. Due to the instability of the local currency against other foreign currencies, contractors find out that inflation affects the prices they had budgeted for thereby leading to losses. Unrealistic contract duration is another risk that affects many projects. Contractors in their bid to win projects propose timelines they are very sure they would not be able to meet. This leads to problems when undertaking the project. Inaccurate estimating also poses as a risk factor. This occurs when due to human errors and oversight, mistakes are conducted in the estimation process. This causes discrepancies when undertaking the construction project thereby leading to problems and dispute. Accurate understanding of the risks causes proper allocation to the party best capable of controlling them. Some risks inherent in the construction process may be readily predicted or easily identified. Others however may be totally unanticipated and unforeseen (Palmer et al., 1996).

Baartz and Longley (2003), the risks that contractors face include poor site conditions, unfavorable weather, insufficient drawing details, delay in gaining access to site, failure of subcontractors to perform, lazy labor force, strikes, defects in construction, penalties, damages, late delivery of materials, costs arising from delayed completion of works (Baartz and Longley, 2003; Palmer et al., 1996). Contractors must consider their responsibility to take insurance and the capability to transfer the risks to consultants, subcontractors or insurers. While clients may be focused primarily on the risk of the project being delayed and overrunning cost, the contractors may be concerned with gaining profits from the project while workers may be pre-occupied with their health and safety in the day to day working atmosphere and environment and the risks of falling sick and being injured in accidents. Furthermore, some risks are unique to a party while others are shareable with other parties (Akinradewo *et al.,* 2020; Baartz and Longley, 2003). This therefore leads to a lot of claims and conflicts in the overall life cycle of the project. The various parties and stakeholders have different perception and knowledge of risk and this reflects in their priorities and objectives. It is best if the risk is placed with the stakeholder that is involved in managing the project and who can best manage the cause of the risk (Akinradewo *et al.,* 2020). In considering an example, a client may control political risks, contractors can deal with safety risks, designers and consultants take care of design defects. Construction insurance therefore covers interests of financiers, clients, subcontractors, contractors, suppliers and engineers (Akinradewo et al., 2020; Baartz and Longley, 2003). Workers' compensation insurance basically covers every liability, whether it arises from common law or statute, in relation to injury or death of persons and employees or people deemed as employees. It is normal for the contractor to be required by the principal to

Table 1. Risk factors associated with contractor insurance provision.

	Descriptive Statistics		
Risk Factors	Mean Item score (MIS)	Relative Importance Index (RII)	Rank
Exchange rate fluctuation	4.24	0.850	1
Unrealistic contract duration	4.13	0.826	2
Inaccurate estimating	3.96	0.792	3
Interference from client	3.93	0.786	4
Mistakes in design documents	3.91	0.781	5
Inadequate contractor experience	3.70	0.738	6
Materials damage	3.52	0.705	7
Errors in drawing	3.41	0.681	8
Labour shortage	3.30	0.660	9
Theft	3.20	0.641	10
Materials shortage	3.15	0.631	11
Shortage of liquidity	3.12	0.620	12
Bad weather	3.08	0.617	13
Acts of God	2.90	0.580	14
Radioactive material	2.64	0.525	15

maintain workers' compensation insurance for all employees involved in undertaking the contract (Rendell and Yablonsky, 2003).

The principal will also seek to endorse the contractor's policy for projects with special and definite risks e.g. in constructing processing facilities for mining companies, endorsements will be required to provide cover for workers working underground and to cover diseases (Baartz and Longley, 2003). The principal will normally want to be named and insured as the principal in the workers' compensation policy of the contractor. This will cover the claims by the employees of contractor who emphasize the principal is the employer (Rendell and Yablonsky, 2003). These findings therefore agree with some of the relevant literature.

4.2.1 *Hypothesis testing*

Analysis of Variance (ANOVA) test was conducted to test the perceptions among the categories of respondents (contractors, consultants and insurers) on the underlying risk factors associated with construction projects in the construction industry of Ghana. The null hypothesis (H0) states that there is no difference in perception among the categories of respondents on these risk factors.

From Table 2, none of the risk factors had significant different perception among the categories of respondents (contractors, consultants and insurers) on the risk factors.

Table 2. ANOVA test results for underlying risk factors.

	df	F cal	F tab	P val.	Sig	Decision
Exchange rate fluctuation	58	0.785	4.00	0.732	NS	Accept
Unrealistic contract duration	58	0.612	4.00	0.673	NS	Accept
Inaccurate estimating	58	0.923	4.00	0.798	NS	Accept
Interference from client	58	0.576	4.00	0.987	NS	Accept
Mistakes in design documents	58	0.609	4.00	0.874	NS	Accept
Inadequate contractor experience	58	0.845	4.00	0.622	NS	Accept
Materials damage	58	0.735	4.00	0.901	NS	Accept
Errors in drawing	58	0.643	4.00	0.703	NS	Accept
Labor shortage	58	0.921	4.00	0.683	NS	Accept
Theft	58	0.795	4.00	0.911	NS	Accept
Materials shortage	58	0.735	4.00	0.901	NS	Accept
Shortage of liquidity	58	0.612	4.00	0.673	NS	Accept
Bad weather	58	0.822	4.00	0.746	NS	Accept
Acts of God	48	0.543	4.00	0.897	NS	Accept
Radioactive material	58	0.765	4.00	0.913	NS	Accept

95% confidence interval, $\alpha = 0.05$

5 CONCLUSION AND RECOMMENDATION

This study concludes that the most underlying factors associated with contractor insurance provision in the Ghanaian construction industry based on analyses of Relative Importance Index for the ranking, reveals that the following factors such as exchange rate fluctuation, unrealistic contract duration, inaccurate estimating, interference from client, mistakes in design documents, inadequate contractor experience and materials damage were considered as most significant risk factors fostering construction contractors to sought of insurance provisions in order to proactively manage the potential impact of the risk. The study further concludes that there no significant difference of perceptions among (contractors, consultants and insurers) on the underlying risk factors associated with construction projects in the construction industry of Ghana. The study further recommended that insurance provisions could assist contractors to proactively manage the construction risk, however, due diligence and other risk management best practice as undertaking an extensive project risk assessment and effective mitigation action plan as it could be less financial involving.

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*Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
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Perception to road risk among informal public transport operators in South Africa

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ABSTRACT: Road traffic accidents remain an unfortunate offshoot of urban transport system. However, there exist limited knowledge on traffic risk and accidents among informal public operators (IPT). This study explored if IPT in Durban, South Africa are at risk of road accidents. Data for this study was sourced from the sample of 150 purposively selected IPT in Durban, South Africa. Samples were drawn from over five taxi ranks in the city. Focus was given to car and mini-bus (known as taxis) that ply within the city. Study findings revealed that age, marital status, and length of operator experience defines operators traffic risk perception. Results shown that traffic risk perception was significantly different between the levels of relationships, $\chi^2(6) = 16.37$, $p = .012$. Younger public transport operators had lesser values for safety wariness compared to older drivers. This calls for improved safety education among younger drivers in the city.

Keywords: Accidents, Durban, Drivers, Public Operators, Risk

1 INTRODUCTION

Mobility is key to urban residents. This is because mobility defines access and wellbeing. Andreasen and Møller-Jensen (2017) reported that access to services, facilities and livelihood opportunities are dependent on modal or mobility options. However, road transport remains the most invested mobility choice in Africa. This is because road transportation (as reflected

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in car dependence) remains the most preferred and common modal choice in sub-Sahara Africa. Despite the global trend against motorized transit, there remains heavy dependence on motorized transport type in Africa. Sietchiping et al. (2012:183) reported that sub-Saharan African (SSA) cities are deploying strategies towards more car-dependent cities at the expense of other modes of urban mobility or at developing a range of private and public transport options. Kumar et al. (2021:22) reported that governments in developing countries are struggling to find the most efficient ways of moving people around burgeoning urban areas.

This increasing road dependence and construction investments according to Calvo-poyo (2020) seems not be a sustainable solution to the increasing road fatality and traffic risk. Perhaps this justifies the reason while it was alluded that road accidents are one of the main negative externalities of road transport, causing suffering and great losses of human capital to society as a whole (ibid:1). It can then be said that motorization which has enhanced the lives of many individuals and societies, but the benefits have come with a price (Gopalakrishnan, 2012) due to road traffic crashes. Road traffic crashes are a global problem and a remains a safety priority issue across the world. This is because road accidents as the leading non-natural death among citizens continues to negatively impact on the economic standing of the countries. For instance, Islam and Dinar (2021) estimates suggest that about 1.2 million die and over fifty million injured worldwide every year in road crashes.

With nearly ninety percent of the road facilities in developing nation (Mirza and Daud, 2013), Kareem (2003) further states that "highest fatality rates (deaths per 10,000 motor vehicles) worldwide occur in African countries, particularly Ethiopia, Uganda and Malawi. These accidents/ crashes compelled the General Assembly to set a target to half the global deaths and injuries by 2030. With rapid population growth and more vehicles being produced, there is a likelihood that accidents will increase year by year, unless strict policies are introduced. In some comparisons, there appears to be an indirect relationship between the country's economic standing and the road crashes, as World Health Organization (WHO) reports that 93% of the world's fatalities on the roads occur in low- and middle-income countries. There are more vehicles in developed countries compared to developing countries due to affordability or economic status of those countries. In order to achieve Sustainable Development goal 11, the targets set by UN for 2030 should be followed and implemented.

Road traffic accidents constitute a significant social problem, and the majority occur in urban and suburban areas. Road traffic crashes appear to be more in urban areas due to the number of driving activity (Bauer et al., 2016). An activity in which IPT contribute to extensively. For instance, in South Africa, traffic crashes remain a leading cause of both injury and death. This remains a health and a social problem for the country as it leaves families destitute. Although the numbers are still high, report from RTMC shows that there is an 8% decrease in 2018 compared to 2017 (OECD, 2019). More volumes of cars are found in urban areas, making it more likely to find more accidents there.

Heinrichs et al. (2016) aver that IPT are an essential part of transport sector in global south. It was alluded that IPT operators supports city mobility condition in the region. Cerveroa and Golub (2007) mentioned that despite the role of informal transport operators in promoting on-demand mobility for the transit-dependent (most especially urban poor), their contribution to traffic congestion, pollution, and traffic accidents cannot be ignored. In South Africa, the author reported on the negative externalities such as death, accidents and para-transit cartel wars and crime that the industry drives. Kumar et al. (2021) mentioned that despite the ability to the informal operators to compliment the walking modal option in sub-Saharan Africa, these group continues to undermine city security and safety. In fact, it was posed that minibuses such as the South African taxis are main cause road accidents and reduced public security. This according to Dumba (2017) can be due to negative, inappropriate and unsafe driving and driver's behaviour generated by informal public transport.

However, few studies such as Dumba's (2017) have moved away from the generic classification of drivers of crashes and accidents in Africa. Going by limited knowledge of the contribution of IPT to both positive and negative urban transit experience. Kumar et al. (2021), reported that informal transport or para transit such as traditional taxi, tricycle (keke), mini vans (danfo) and motorcycles (Okada) are the preferred means of transportation for many people in cities of developing countries characterized by the informality of services. Evans et al. (2018) argued that despite the relevance of informal transport to the mobility of city populations, it remains excluded in policy development and planning in developing countries.

Most transportation studies over the years have focused on road traffic accidents as an unfortunate offshoot of an urban transport system. To reduce these crashes, Honelgn and Wuletaw (2020) suggest education of proper use of sideways by pedestrians and regular vehicle examination to ensure roadworthiness. Butans et al. (2015) suggest constant increase in intensity of road traffic and the allowed speed limits seem to impose stronger requirements on road infrastructure and use of road safety systems. There is an existing gap in understanding accident risk perception among IPT. The view is that the individual preconceived and perceived notion is key to experience and events. This is asserted in the view that behaviour is key to choices individuals and households make with reference to their day-to-day travel or traffic activities. Likewise, the argument is within the roles of IPT operators in urban mobility in Africa and in this study South Africa. However, in this study, the authors argue that risk exposure is embedded in human behaviour and perception to risk exposure. This is in line with the view of Blamah et al. (2021), the mindset (perception) is key to behaviour. Thus, the authors recognise the need to proffer answer to the question of if informal public transport operators in Durban are at the risk of accidents?

2 RESEARCH METHODOLOGY

As exploratory research, the study question was to know if informal public transport operators in Durban were at the risk of accidents. Thus, sample for the study was drawn using non-probabilistic sampling technique. The techniques adopted were purposive, convenient, and accidental sampling. Considering that the study targeted IPT operators in Durban city, the drivers sampled were mainly informal operators. Informal operators in Durban are classified into car and mini-buses (known as taxis) drivers (Figure 1).

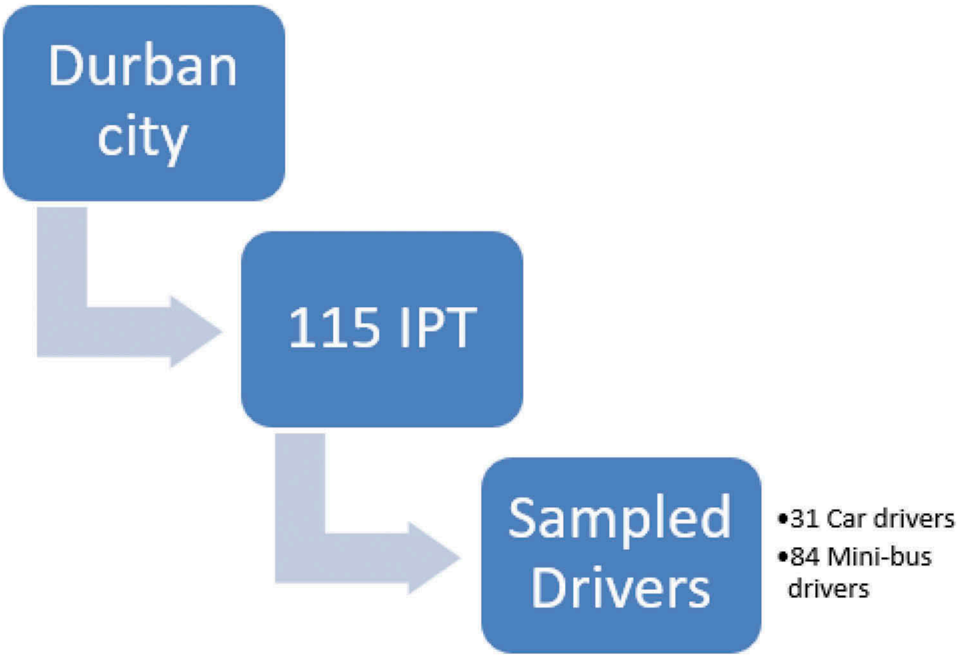

Figure 1. Stepwise methodological same approach.

Regarding measures used in this study, two safety perception questions was asked, while the safety climate sub-scale of the safety attitude questionnaire (SAQ) Sexton et al. (2016) was used to measure safety climate. The sampled drivers were drawn from across the conveniently and purposively selected taxi rank or parks within the city. Access to parks and ranks, was based on discussion and approval from the rank marshal and in the case of Chesterville association, approval from the association office. Focus was given to buses and cabs that ply within the city area of Durban (see Figure 2). The drivers were interviewed using accidental and convenient sampling because not all drivers at the park or rank were available for the study.

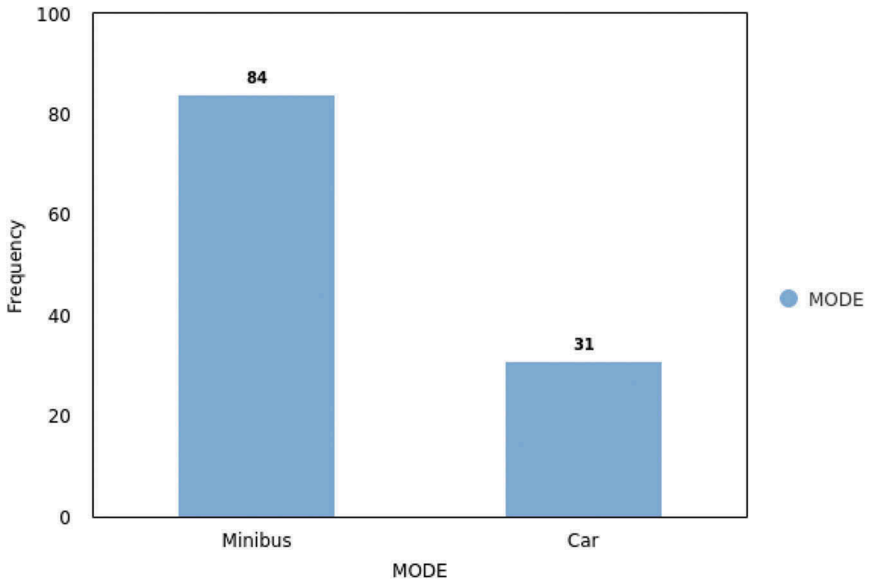

Figure 2. Type of informal public transport operator sampled.

In total, one hundred and fifteen IPT operators were sampled across the five conveniently sampled taxi or cab ranks/parks (see Figure 3). All drivers were interviewed using English Langauge or the Zulu native language over a three-day period. Use of English language was common among immigrant public cab drivers in the city.

3 DATA ANALYSIS

A Cronbach alpha coefficient was calculated for the Safety Wariness Perception, Crash Likelihood Perception, and Traffic Risk Perception Scales. The Cronbach's alpha coefficient was evaluated using the guidelines suggested by George and Mallery (2018) where > .9 excellent, > .8 good, > .7 acceptable, > .6 questionable, > .5 poor, and ≤ .5 unacceptable.

The items for the scales had a Cronbach's alpha coefficient of .90, .86, and .85 for Traffic Risk Perception, Safety Wariness Perception, and Crash Likelihood Perception Respectively. Thus, indicating excellent reliability for Traffic Risk Perception Scale, and good reliability for Safety Wariness Perception, and Crash Likelihood Perception Scales. Table 1 presents the results of the reliability analysis.

A total of 115 public transport operators took the survey. Frequencies and percentages were computed for age, relationship, and education. The most frequently observed category of Age was 25-34 (n = 40, 34.78%). Majority of respondents belong to the male category of gender (n = 114, 99.13%). While many of the respondents were single, but never married

Figure 3. Spatial location of sample taxi ranks.

Table 1. Reliability table.

Scale	No of Items	Alpha
Traffic Risk Perception	2	0.902
Safety Wariness Perception	4	0.857
Crash Likelihood Perception	3	0.845

(n = 57, 49.57%). The most frequently observed category of Education was Matric/Secondary School (n = 95, 82.61%). Frequencies and percentages are presented in Table 2.

The observations for years of driving experience had an average of 9.85 (SD = 6.50, Mdn = 8.00, Mode = 5.00, Skewness = 1.16, Kurtosis = 1.01). The summary statistics can be found in Table 3.

A Kruskal-Wallis rank sum test was conducted to assess if there were significant differences in safety wariness, crash likelihood perception, and traffic risk perception between the levels of age, level of education, and marital status. Safety wariness was significantly different between the levels of Age, $\chi^2(5) = 12.59$, $p = .028$. Safety Wariness was similar for each level of Education, $\chi^2(3) = 7.76$, $p = .051$. Safety wariness was similar for each level of relationship $\chi^2(6) = 12.23$, $p = .057$. Crash likelihood perception between the levels of age were the same, $\chi^2(5) = 3.72$, $p = .591$. Crash likelihood perception was similar for each level of education, $\chi^2(3) = 0.95$, $p = .814$. Crash likelihood perception was similar for each level of relationship, $\chi^2(6) = 2.57$, $p = .861$. Traffic risk perception was significantly different between the levels of age, $\chi^2(5) = 12.03$, $p = .034$. Traffic risk perception was similar for each level of education $\chi^2(3) = 3.47$, $p = .325$. Traffic risk perception was significantly different between the levels of Relationship, $\chi^2(6) = 16.37$, $p = .012$. Table 4 presents the results of the Kruskal-Wallis rank sum test.

Table 2. Frequency table for age, relationship, and education.

Variable	n	%
Age		
18-24	4	3.48
25-34	40	34.78
35-44	38	33.04
45-54	20	17.39
55-64	11	9.57
65+	2	1.74
Gender		
Female	1	0.87
Male	114	99.13
Relationship Status of Operators		
Married	32	27.83
Widowed	1	0.87
Divorced	4	3.48
Separated	6	5.22
In a domestic partnership or civil union	2	1.74
Single, but cohabiting with a significant other	13	11.30
Single, never married	57	49.57
Education Status of Drivers		
No Formal Education	2	1.74
Primary School	11	9.57
Matric/Secondary School	95	82.61
Undergraduate Degree (NCE, OND, HND, B.Sc, B.A, B.Tech, B.Eng)	7	6.09

Note. Due to rounding errors, percentages may not equal 100%.

Table 3. Summary statistics table years of driving experience.

Variable	M	SD	Mdn	Mode
Years of Driving Experience	9.85	6.50	8.00	5.00

Table 4. Kruskal-Wallis rank sum test.

	Factors	χ^2	df	p
Safety Wariness	Age	12.59	5	0.028
	Level of Education	7.76	3	0.051
	Marital Status	12.23	6	0.057
Crash Likelihood Perception	Age	3.72	5	0.591
	Level of Education	0.95	3	0.814
	Marital Status	2.57	6	0.861
Traffic Risk Perception	Age	12.03	5	0.034
	Level of Education	3.47	3	0.325
	Marital Status	16.37	6	0.012

A Pearson correlation analysis was conducted among years of driving experience, traffic risk perception, crash likelihood perception, and safety wariness. A significant positive correlation was observed between crash likelihood perception and safety wariness, with a correlation of .42, indicating a moderate effect size ($p < .001$). This suggests that as crash likelihood perception increases, safety wariness tends to increase. No other significant correlations were found. Table 5 presents the results of the correlations.

The result of the correlation is in line with the findings of Oah et al., (2018) and Pandit et al., (2018). In both studies, there was a significant relationship between safety risk perception and recognition of hazard.

Table 5. Pearson correlation results among driving experience, traffic risk perception, crash likelihood perception, and safety wariness.

Combination	*r*	*p*
Driving Experience-Traffic Risk Perception	.19	.211
Driving Experience – Crash Likelihood Perception	.15	.334
Driving Experience-Safety Wariness	.16	.334
Traffic Risk Perception-Crash Likelihood Perception	.04	.872
Traffic Risk Perception-Safety Wariness	.07	.872
Crash Likelihood Perception-Safety Wariness	.42	< .001

4 LIMITATIONS AND IMPLICATIONS OF RESEARCH

The study has a number of limitations. First, the study is part of a comparative, and exploratory study which sought to compare driver wellbeing, safety attitude and workplace harassment between Durban, South Africa, and Ibadan, Nigeria. However, due to logistics reasons the Nigerian dataset was not available as at the time of the call. Thus, we could only utilize the South-African data. Secondly, because the informal transport sector is dominated by the male operators; thus, we could not get a sizable number of female informal transport operators to do a gender comparison. Given the limitations, future research should extend these results to formal transport operators, as a sizable number of female operators exists in the formal transport sector. Furthermore, since an informal transport operator's perception to crash likelihood increases with the operator's safety wariness, it is important to make the road environment such that it reduces the operator's perception to crash likelihood. Furthermore, for further research, it would be important to determine the causal relationship between safety wariness, and crash likelihood.

5 CONCLUSIONS

The main question asked in this study was if informal public transport operators in Durban are at the risk of accidents? Based on the study evidence, it was revealed that demographic variables of age, marital status and length of operator experience defines operators traffic risk perception. It was revealed that younger public transport operators in Durban had lesser values for safety wariness compared to older drivers. This was evidenced in younger transport operators had a mean rank of 54.59 (18-54 years), while older transport operators had a mean rank of 89.37 (55 + years). This is expected as younger transport operators seems to worry less about safety on the road while driving: this also relates to their risky decisions while driving. Similarly, transport operators aged between 25 – 34 years old have the least traffic risk perception (49.65), while transport operators aged 65+ had the highest traffic risk perception. However, transport operators aged 18-24 years have a higher traffic risk perception compared to transport operators aged 25 - 34 which might be because they are mostly new drivers learning how to drive, and as a result, they are very cautious. Although, Brown and Groeger (1988:585) wrote that young drivers are statistically overrepresented in road accidents. This evidence may somewhat relate to the view of Okokon et al. (2015), that age remains a driver of road annoyance and risk perception. The argument was that age remains a determinant of physical and environmental stimuli that influence risk perception. Such physical feature which Rankavat and Tiwari (2016) reported are built-environment features that promotes risk perception.

However, transport operators who are divorced seemed to have the lowest traffic risk perception (19.50), probably because of emotional trauma derived from the divorce process. Lastly, the relationship between crash likelihood perception and safety wariness is direct and has a medium effect size, indicating that as crash likelihood perception increases, safety wariness also increases.

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Quality and resilient infrastructure

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Systematic review: Prioritization models for asphalt road maintenance

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ABSTRACT: Transportation infrastructure serves as an economic and development driver as it provides connectivity to social and economic amenities and offers a vital link between production and consumption. Better-maintained roads lead to enhanced connectivity and societal advantages. The decision on which road to maintain is a complex decision-making problem faced by public authorities. Multi-criteria decision-making prioritization models, influenced by a variety of decision parameters, are designed for such problems. In this paper, the authors adopt a systematic review methodology in analyzing models developed by scholars aimed at prioritization of which asphalt paved road to maintain or rehabilitate. The primary contribution of this study is the ability of the authors to identify that the available multi-criteria decision-making prioritization models for asphalt paved road maintenance fail to address the concerns of Africans and little effort is made in capturing emergent concerns related to the inclusion of socio-economic and environment aspects.

1 INTRODUCTION

One of the most important things for a country's growth is its transportation infrastructure. Transportation infrastructure serves as an economic and development driver as it provides connectivity to social and economic amenities and offers a vital link between production and consumption (Tini et al. 2018; Datta and Sahu, 2021). Road infrastructure plays an even stronger role in Zambia's economy it been a landlocked country (Road Development Agency, 2014; Mwila, 2019). Having seen this, the Government has taken initiatives within the country's overall strategic framework of transforming Zambia from a landlocked country to a land-linked country and Government has thus invested in several big scale road development projects (Road Development Agency, 2014; NRFA, 2019).

However, these roads if not well-maintained result in a loss in enhanced connectivity and societal advantages (Tini et al. 2018; Datta and Sahu, 2021). In Zambia, and many countries globally, asphalt pavements are the predominantly constructed paved roads that form part of public road networks (state owned and everyone has right to use) (Road Development Agency, 2014; Mwila, 2019; Liu et al. 2020). In this study bituminous pavements do not refer to bitumen-sealed roads but to bitumen bound asphalt pavements (Douglas, 2015; Tharun, 2017). Therefore, bituminous pavements are synonymous to asphalt pavements in any and all discussions drawn in this study. Asphalt is made in a plant that heats, dries, and combines aggregate, bitumen, and sand (Douglas, 2015; Liu et al. 2020).

Every pavement, no matter how well-designed or constructed, will deteriorate over time due to the combined effects of traffic loading and the environment (Llopis-Castelló et al. 2020). We use maintenance treatments to slow down or stop the deterioration process and in so doing extend the

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pavement life. Firstly, these treatments can be as simple as routine works (carried out with regularity) such as grass cutting along the roadside, cleaning of silted drainages and culverts, patching, road marking, and porthole repair for instance. Secondly, these treatments can include major maintenance works that consist of destructive activities before applying the treatment and include for example resurfacing, overlay, and rehabilitation corrective treatments. Lastly, maintenance can consist of urgent maintenance treatments for roadways that require prompt attention effective to culverts that have collapsed or landsides that have blocked roads, or washaways for example (Vaitkus et al. 2016; Pamuković et al. 2021). Road and local authorities rely on pavement management systems to plan and manage the maintenance of road network infrastructure and other supporting infrastructure. This is a system that contains defined standards and procedures used to collect, analyze, maintain and report pavement condition data, which is then used to aid decision makers in coming up with strategies for maintaining pavements in deplorable state (Mwila, 2019). Further, pavement management can consist of prioritization of which roads to maintain, which is the focus of this study.

While pavement maintenance is a specialized area of local government responsibility, executing a long-term preventative maintenance strategy may provide significant environmental, economic, and social benefits (Mengistu et al. 2020; Di Mascio et al. 2021). However, road and local authorities globally are faced with the problem of pavement maintenance project prioritization (Masoumi, 2016; Yannis et al. 2020). This is because the decision on which road to maintain or rehabilitate is a multi-criteria decision-making complex problem further constrained by budget allocations (Tscheikner-Gratl et al. 2017; Yannis et al. 2020). This necessitates a model able to handle the complexity of this decision-making and MCDM models are designed to handle multi-criteria influencing the prioritization of which roads to maintain (Mardani et al. 2015; Tscheikner-Gratl et al. 2017; Yannis et al. 2020).

These multi-criteria could include decision parameters related to pavement deterioration, road safety, cost, economic, social, and environmental concerns (Abu Dabous et al. 2020; Arshad et al. 2021). Sustainability (Arshad et al. 2021; Pamuković et al. 2021) and, more especially, social and environmental factors are becoming increasingly important in pavement management decision-making (Bardeesi and Attallah, 2015; Abu Dabous et al. 2020) Other concerns include aspects that influence the functionality of the road such as: (a) rider comfortability (Ragnoli et al. 2018); (b) serviceability (Vaitkus et al. 2016); (c) aesthetics (Parekh and Shah, 2016); (d) road width; and (e) road markings (Erastus Mishengu Mwanaumo and Kelvin Lungu Agabu, 2021), for instance.

The objective of this study is to identify the gaps in the available multi-criteria decision-making models developed by scholars for the prioritization of alternative asphalt paved roads needing maintenance. The next section presents the methodology the authors adopt in this paper.

2 METHODOLOGY

In this paper, the authors adopt a systematic review methodology in analyzing models developed by scholars aimed at prioritization of which asphalt paved road to maintain or rehabilitate. This included (i) search and appraisal: selection of which papers to include in this study; (ii) synthesis: extracting and categorizing data from these selected papers; and (iii) analysis: examining of this extracted data. Firstly, this study utilizes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach in selecting which papers to include in this study. Figure 1 illustrates how the authors selected studies to include in the systematic review of this paper.

The selected papers included in this study were appraised from a pool of literature identified from electronic sources and search engines limited to the two key constructs illustrated in Figure 1. Papers eliminated included publications before 2010 and those not relevant to the scope of this study following a full text review.

In this paper, 15 studies were finally included in the analysis of scholarly works published. The authors firstly categorized the data of each study based on the type of prioritization model, and analyzed the methodology and findings based on this extracted data. In analyzing the methodologies and findings in these papers, the authors examined how MCDM theories where adopted and decision-criteria aspects each model is based on. The next section presents these analyses.

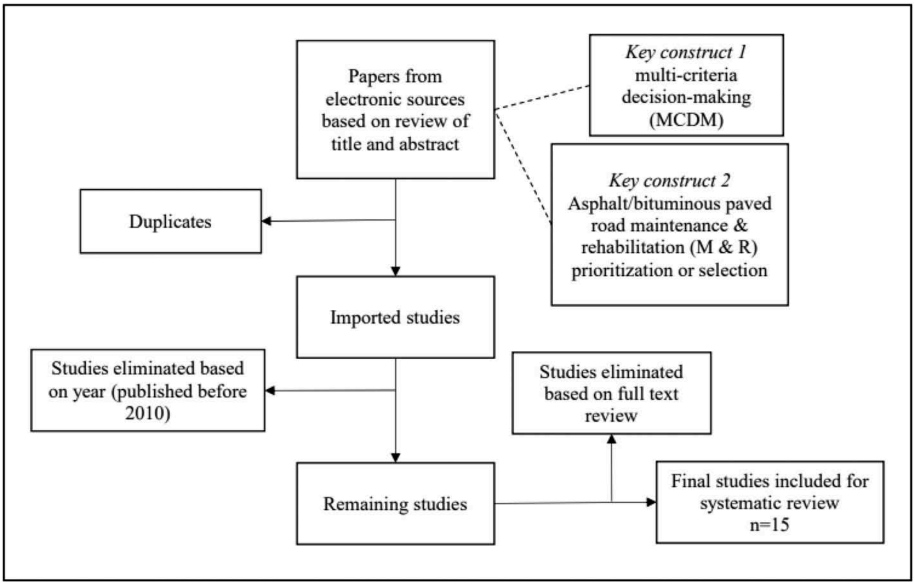

Figure 1. PRISMA framework for final studies included for systematic review.
(source: author)

3 PRIORITIZATION MODELS FOR ASPHALT PAVED ROAD MAINTENANCE

The authors present in this section, firstly, a generalized cross examination of the models developed by the papers included in this paper's systematic review of literature. The models examined in this study are categorized as (i) Analytic Hierarchy Process (AHP); (ii) Fuzzy; and (iii) Hybrid models.

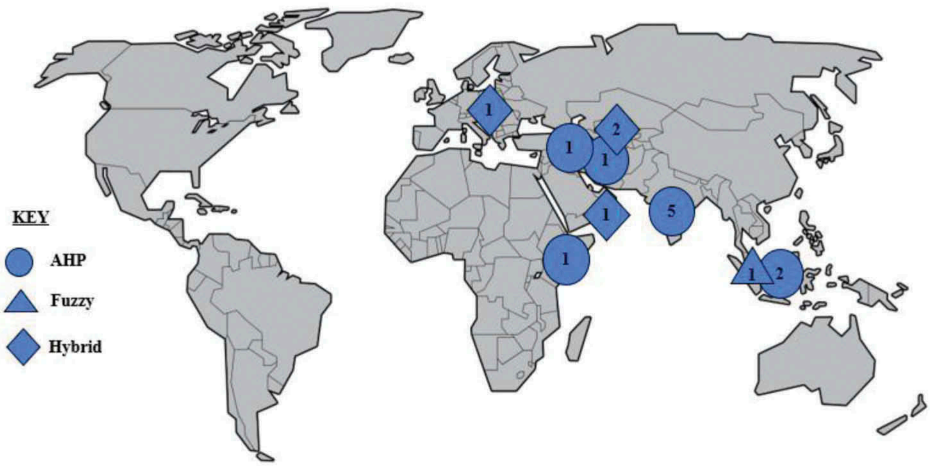

Figure 2. Models developed in geographical context.
(source: author)

3.1 *General*

MCDM for pavement maintenance is not unique to Africa (Nautiyal and Sharma, 2021; Pamuković et al. 2021; Spits Warnars et al. 2021). Figure 2 illustrates the models developed across the world in the papers reviewed in this paper.

However, the social and geographic context, of even comparisons among developing countries, influence the prioritization needs of each country (JICA, 2013; AfDB, 2018; Calderon et al. 2018; World Bank, 2018). Following the review of literature, scholarly work in developing economies were all in non-African countries (Figure 3) with the exception of a study in Ethiopia by Mengistu et al. (2020).

AHP was determined as the pre-dominantly used multi-criteria decision method in relevant reviewed literature (Figures 2-3). Even for authors that developed hybrid models they took advantage of utilizing the AHP method (Figure 3) in weighting decision-criteria parameters.

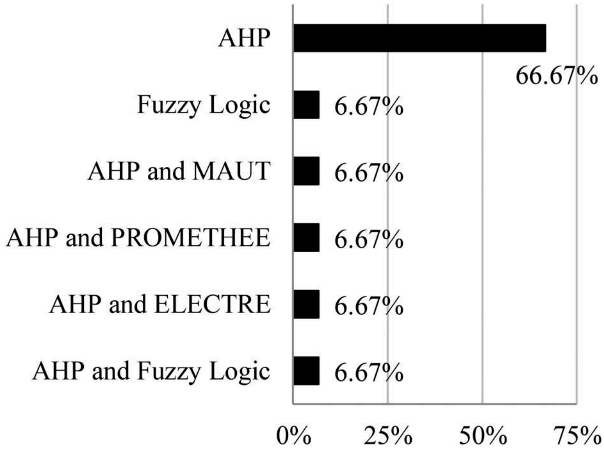

Figure 3. Percentage from reviewed papers (n=15): MCDM theory adopted.
(source: author)

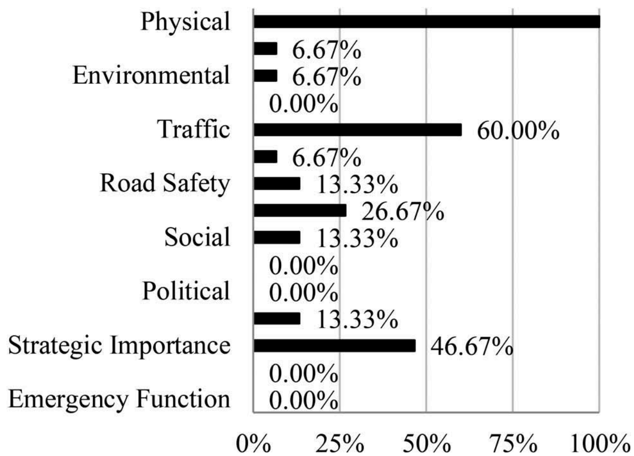

Figure 4. Percentage from reviewed papers (n=15): Decision-criteria aspects captured.
(source: author)

Little effort has been made by scholars in orienting their models to have ranking criteria-goals lined with other than physical, traffic, and strategic importance aspects (Figure 4). The most popular objective of these models is based on physical related decision-criteria aspects.

This is even though some of these omitted aspects are of emergent concerns discussed in the transport sector. An example is environ-mental and climate change related issue, which are emergent concerns in infrastructure development and maintenance (Dikanski et al. 2017; Achebe and Tighe, 2018; Gokasar et al. 2021). Only Abu Dabous et al. (2020) make an effort to at least have environmental sustainability as one of the decision-making influencing variables incorporated in their MCDM model. Despite this, all these authors fall short of intricately including environmental and climate change decision-criteria aspects in their MCDM models. On the other hand, even though clearly, economic viability is a significantly rating criteria (Kulkarni and Miller, 2007; Masoumi, 2016), most scholars have not incorporated it at all in their models. Studies by: Moazami et al. (2011); Ibraheem and Atia (2016); Parekh and Shah (2016); Rose (2016); Ahmed et al. (2017); Suthanaya (2017); Bhuva et al. (2019); Mengistu et al. (2020); Spits Warnars et al. (2021), all present papers with a bias in prioritization based on predetermined criteria. This is a bias because, based on each study's decision-criteria aspect objectives, the problem of decision-making is only influenced by these criteria with the exclusion of possibly more important variables from other aspects.

Predominantly, with the exception of Pamuković et al. (2021), there is a bias in the survey respondents involved in establishing criteria by limiting responses collected to planning and implementing authorities. Furthermore, the authors limit their respondents to pre-conceived necessary informants. This eliminates the exclusion of respondents with possibly valuable contributions towards establishing important decision-criteria aspects. This suggests the weakness of taking a purposive sampling approach alone.

3.2 *Analytic -Hierarchy process model*

3.2.1 *Authors adopting the AHP methodology*

Authors that utilized only AHP theories, illustrated in Table 1, had similar shortcomings characteristic to this theory. Therefore, the primary concern is that these papers fail to capture the subjectivity of human judgements when developing crisp values from verbal assessments. On the other hand, utilizing this theory provided authors with the opportunity to develop hierarchical structure of predetermined or established criteria. Thus, presenting a model with clear focus on the decision-criteria and sub-criteria, and their allocated weights developed from these crisp values. These studies were focused on basic simple models for expert choice project selection from prioritized deteriorated roads for a study area. Therefore, their primary concern was to rank selected roads based on a simple approach and less diverse decision-criteria aspects.

Table 1. AHP standalone models.

MCDM Model	Author, Country	Decision-Criteria Aspects
Analytic Hierarchy Process (AHP)	Mengistu et al. (2020), Ethiopia Bhuva et al. (2019), India Ahmed et al. (2017), India	Physical
	Spits Warnars et al. (2021), Indonesia	Physical; traffic; and economic
	Nautiyal and Sharma (2021), India	Physical; traffic; and accessibility
	Suthanaya (2017), Indonesia	Social and accessibility; strategic importance; physical; and traffic
	Rose (2016), India	Physical and strategic importance
	Parekh and Shah (2016), India Moazami et al. (2011), Iran	Physical; traffic; and strategic importance
	Ibraheem and Atia (2016), Iraq	Type of treatment; and physical

(source: author)

These models prioritize options using a pairwise comparison method, hence rankings derived from these models are susceptible to discrepancies in evaluation and ranking criteria. The fact that the general version of AHP is vulnerable to rank reversal is one of its main complaints. The addition of alternatives at the end of the process might cause the final rankings to flip or reverse due to the nature of comparisons used for rankings. The authors argue that these models are not the best for use in real-world situations.

Regardless of the social context and whether parameters were established or predetermined, these studies limited their hierarchical objectives to physical, traffic and strategic importance aspects. Suthanaya (2017) attempts to include social and accessibility aspects but the author limits accessibility decision-criteria to socio-cultural aspects. Accessibility to amenities related to for instance roads with economical, agricultural, and developmental importance, could be important influence factors captured as under this decision-criteria aspect.

3.2.2 *Limitations*

These models all fail to capture established emergent concern decision-criteria aspects associated to African social context. Even the study conducted in Africa, Ethiopia, falls short because of the aforementioned bias. Further, they fail to capture the subjectivity of human judgements when developing crisp values from verbal assessments.

3.3 *Fuzzy and AHP-fuzzy hybrid models*

3.3.1 *Authors adopting the Fuzzy and AHP-fuzzy methodologies*

Utama et al. (2016) adopt the fuzzy logic as a stand-alone method in developing their model, illustrated in Table 2. The biggest drawback of using fuzzy logic on its own, is its inaccuracy weaknesses in project ranking. Fuzzy logic plays an important role in this study, in handling uncertainty of subjective datasets utilized as model inputs, which is one of its most notable strengths. However, the biggest drawback of using fuzzy logic on its own, in developing this study's decision matrix, is its inaccuracy weaknesses. Thus, a less robust model com-pared to the fuzzy-AHP model developed by Moazami et al. (2011), which gets the best of both fuzzy logic and AHP models.

Table 2. Fuzzy and AHP-fuzzy hybrid models.

MCDM Model	Author, Country	Decision-Criteria Aspects
Fuzzy Logic	Utama et al. (2016), Indonesia	Strategic importance; physical; economic; and traffic
Analytic Hierarchy Process (AHP) and Fuzzy Logic	Moazami et al. (2011), Iran	Physical; traffic; and economic

(source: author)

Similar to the other AHP based model studies, the fuzzy-AHP model developed by Moazami et al. (2011) is focused on expert choice of project selection from prioritizing deteriorated roads for a study area. However, the authors take a fuzzy modelling approach to further explore the Analytic Hierarchy Process (AHP) pair-wise weighted-criteria developed from the previous study's data sets. This paper utilizes the fuzzy approach to give more precision to the outcome choices in rating of criteria (Moazami et al. 2010; Ishizaka, 2014). The authors achieve this through the help of human inference engines, which test logic and rationality of survey respondents (Moazami et al. 2011), were also tested in this study. Product engine, Dienes–Rescher and Lukasie-wicz were the human inference engines tested in this study with findings presented in this paper indicating the Product engine approach as the best and most logical for this data set. Applying fuzzy modelling adds confidence to final rating outcomes.

The biggest drawback of the model developed by Mo-azami et al. (2011) is that its hierarchical objective is also limited to less diverse decision criteria aspects, as in the AHP models developed by the other scholars.

3.3.2 *Limitations*
Both fuzzy methods by Utama et al. (2016) and Moazami et al. (2011) fail to capture established emergent concern decision-criteria aspects associated to African social context and are limited to physical, traffic and strategic importance aspects which are considered the conventionally primary aspects.

3.4 *Other hybrid models*

3.4.1 *Authors adopting hybrid methodologies other than the AHP-fuzzy*
In the purview of this study, content analysis of literature indicates that even for the models developed using Multi-Attribute Utility Theory (MAUT) and Outranking methods, these authors integrated the AHP method in their presented models as presented in Table 3.

Table 3. Other hybrid models.

MCDM Model	Author, Country	Decision-Criteria Aspects
Analytic Hierarchy Process (AHP) and Multi-Attribute Utility Theory (MAUT)	Abu Dabous et al. (2020), United Arab Emirates	Environmental; strategic importance; physical; and road safety
Analytic Hierarchy Process (AHP) and a family of Elimination Et Choix Traduisant la Realite (ELECTRE) outranking methods (ELECTRE II, III and IV)	Sayadinia and Beheshtinia (2020), Iran	Physical; traffic; and economic
Analytic Hierarchy Processing (AHP) and Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) outranking method	Pamuković et al. (2021), Croatia	Strategic importance; traffic; safety; physical; and economic

(source: author).

Abu Dabous et al. (2020) present a framework paradigm based on developing a representative set of utility functions using a combined AHP and MAUT; and ranking networks of pavement sections while incorporating sustainability-related criteria. This study takes advantage of utilizing a hybrid model. By calculating the optimal utility and assigning a utility to each potential result, MAUT, an anticipated utility theory, may determine the optimum course of action in a given scenario. The main benefit of MAUT is that it accounts for uncertainty. However, this model lacks robustness, and has reliability concerns in project ranking.

Compared to the other AHP based models, reviewed in this study, this model attempts to further align the hierarchical objectives to environmental and road safety aspects. However, similar to models developed by the other scholars, the authors present a model that falls short of including climate change decision-criteria aspects. In utilizing the MAUT, in final project rankings, the authors successfully quantify qualitative data sets systematically. Utilizing this theory also allows the direct comparison of several diverse measures. The biggest bias of the model developed in this study is its failure to outrank alternatives based on conflicting criteria. The authors present a concern in the practical implementation of this model, especially because of its reliance on leaving subjective assessments of the values of attribute variables unchecked.

Pamuković et al. (2021) and Sayadinia and Beheshtinia (2020) pre-sent hybrid AHP models developed by integrating PROMETHEE and ELECTRE outranking methods, respectively.

Comparing these outranking techniques to decision support tools like the MAUT, the ability to handle ordinal and mostly descriptive data about the various plans to be examined is a key bene-fit. Additionally, fuzzy relations based on preference and indifference thresholds can be used to account for the ambiguity around the values of the criterion variables. As a result, it enhances fuzzy logic theories. On the other side, the fundamental disadvantage of the outranking approaches is the difficulty in interpreting the findings.

3.4.2 *Limitations*

There are seemingly benefits associated with taking a hybrid approach in combining ELECTRE methods, with the AHP, in the model developed by Sayadinia and Beheshtinia (2020): (i) assessing the degree of credibility; and (ii) in discarding unacceptable project alternatives. However, more effort is needed in building confidence in such a complex model through intensive reliability checks at different levels, which was not the case in this study. With the AHP-PROMETHEE hybrid model developed by Pamuković et al. (2021), the model fails to resolve any uncertainty in subjective data collected as inputs for building this model. The models developed in both studies are biased towards less diverse decision criteria aspects having a hierarchical objective limited to physical, strategic importance, and traffic aspects. Further, both models fail to capture established emergent concern decision-criteria aspects associated to African social context.

4 CONCLUSION

This study aimed at identifying the gaps in the available multi-criteria decision-making models developed by scholars for the prioritization of alternative asphalt paved roads needing maintenance. Based on the limitations presented in cases stand-alone theories are adopted, hybrid models take advantage of combining theories. However, accuracies of hybrid models are subjective to uncertainties and bias depending on the methodology of data collection and analytics in establishing model decision-criteria aspects.

The primary contribution of this study is the ability of the authors to identify that the available multi-criteria decision-making prioritization models for asphalt paved road maintenance fail to address the concerns of Africans. On the other hand, with available models, little effort is made in capturing emergent concerns related to the inclusion of socio-economic and environment aspects. These were considered as the key findings of this study.

Following these key findings, the authors recommend the development of models that would address the concerns of Africans including socio-economic and environment aspects.

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An investigation into the causes of delays in the construction of Metro Rail Projects in India

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ABSTRACT: Metro Rail Projects provide essential infrastructure and contribute significantly to urban connectivity. In India presently, close to 500 km of metro rail development is happening across 15 major cities. However, most metro projects are witnessing substantial delays in completion. The present paper intends to present the results of a study on causes of delays in Indian Metro Projects, through a questionnaire survey of professionals. Fifty-one causes were identified from the literature and are ranked based on the Relative Severity Index (RSI). Seventy-five valid responses were obtained. Responses were subjected to statistical analysis with SPSS software and reliability analysis, ANOVA tests were conducted. Permission from local authorities, change in material prices, change in government laws and regulations, and poor labour productivity were found to be the highly ranked delay causes. The study contributes to identify causes and take up appropriate measures to mitigate the delay and complete projects faster.

1 INTRODUCTION

Construction projects act as the essential link for infrastructure development (Prasad et al.2019a) and also contribute significantly to employment generation. It is estimated that the industry also employs 7% of the working population globally (McKinsey Global Institute, 2017). In India, the construction industry contributes nearly 8% of the Gross Domestic Product (GDP). Growing population, increasing urbanization, and industrialization have put severe stress on the present state of infrastructure (Prasad et al. 2019b). The industry in India is very vital, as India has a huge infrastructure deficit that needs to be quickly filled through the development of essential infrastructure that too within a very quick time.

However, it is noticed that the construction industry is yet to gain that momentum and meet the requirements of the country. The trend of project delays in India, monitored by the Ministry of Statistics and Programme Implementation (MOSPI) shows that out of a total of 1700 projects,

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almost 30% of the projects are delayed with a cost overrun of almost 20% on these projects. While there was a period of slightly better performance from 2015 to 2017, the recent trend has again continued towards deterioration. Figure 1 displays this trend of project delays in India.

Metro projects are increasingly providing the much-needed urban connectivity and at the same time minimizing the traffic congestion, pollution, and also ease of commuting. The government of India has also taken up many metro projects in Tier-II cities and also expanding on the already available network in Tier 1 cities. In India presently, close to 500 km of metro rail development is happening across 15 major cities. However, most metro projects are witnessing substantial delays in completion. It is very essential to investigate the root causes of delay in these metro projects so that the essential infrastructure is delivered on time, and within the budget.

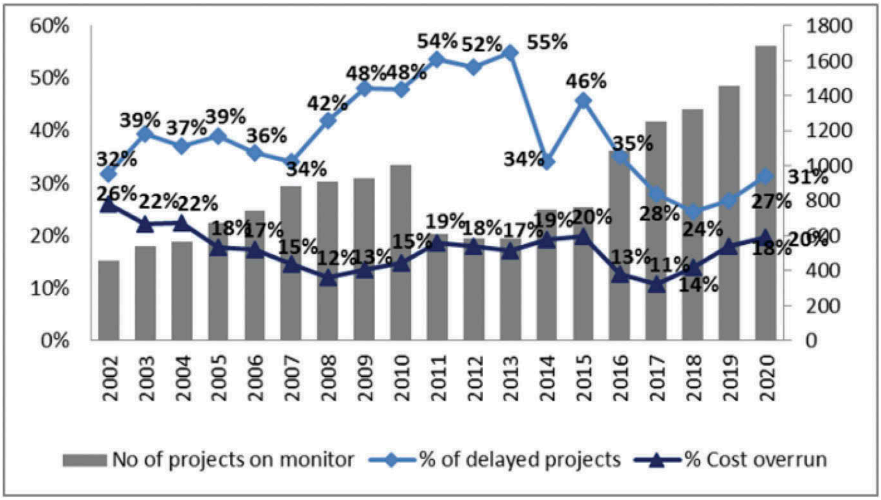

Figure 1. The trend of project delays in India (MOSPI, 2017, Prasad & Vasugi, 2017).

The delay statistics shown in Figure 1 reveal the picture of overall construction project delays in India. However, it is worthwhile understanding the specifics of metro project delays, and the details of completion of some of the mega metro projects under development (MOSPI, 2021) are summarized in Table 1.

Table 1. Delay statistics of the major metro rail projects in India.

S No	Package	Phase	Date of Original Completion	Date of Anticipated Completion	Delay in months
1	Ahmedabad Metro Rail	I	Dec 2018	Aug 2022	44
2	Bangalore Metro Rail	II	Feb 2019	Jun 2024	64
3	Chennai Metro Rail Ext.	I	Mar 2018	Mar 2021	36
4	Mumbai Metro Line 3	III	Jan 2015	Mar 2023	98
5	Delhi Metro Rail	III	Mar 2016	Sep 2021	66

As it can be seen the delays on the projects are extensively high with some of the delays equivalent to the original contract duration itself and this calls for a study on understanding the causes of project delays so that the same can be taken up for mitigation. The present study intends to identify the major causes of delay in the construction of metro rail projects in India. This is one of the first studies investigating the delay causes in Indian metro projects and through this study the authors intend to bring the crtitical causes of delay and can help in institutionalizing appropriate mitigation measures by the authorities and ensure successful urban infrastructure development and connectivity aimed at increasing the economic benefits to Indian urban population.

2 LITERATURE REVIEW

Construction delays and investigation of the reasons attributable to the delays has attracted the interest of the research community for many years now. There have been numerous studies in the past both within India and across the world, carried out to investigate the delay causes in construction projects. The following section describes the various studies carried out investigating the delay causes in projects of varied sectors and types.

2.1 *Studies in road /urban transportation projects*

A study was conducted by Zhang et al. (2020) to investigate the delay causes for subway tunnel projects in China. The authors conducted a questionnaire survey and 49 delay causes were identified. The study found national policy, complications with the geology and conditions, owners' delay of payments, strategy of awarding the contract to lowest priced bidder etc. as the critical delay causes.

Aziz & Abdel-Hakkam (2016) carried out a study investigating the delay causes in road projects in Egypt. A questionnaire survey was conducted and the Relative Importance Index (RII) was adopted as the parameter for ranking the causes of delay. Owner financial problems, conflict/war, slow land expropriation, mistakes in soil investigation, and coordination difficulty between stakeholders were identified as the top causes of delay.

Honrao & Desai (2015) conducted a study on the causes of delays in Highway infrastructure projects in India and identified difficulties in obtaining work permits, traffic diversion issues, unidentified/incorrectly located utilities, designer interface about utilities, and lack of availability of the drawings as the most significant causes of delay.

2.2 *Studies in building projects*

Durdyev et al. (2017) conducted a study to assess the causes of delay for residential construction projects in Cambodia. The authors conducted a survey of the consultants and contractors and the causes were ranked based on Relative Importance Index (RII). The study identified material shortages, material delivery delays, unrealistic scheduling of the project, skilled labour shortages as the top attributes of delay.

McCord et al. (2015) conducted a study to investigate the delays in housing projects in Ireland. 75 attributes of the delay were adopted to be taken up for the questionnaire survey. Deficiencies in site management, ineffective communication strategies, and lack of coordination were found to be the key causes of delay.

Abd El-Razek et al. (2008) conducted a study to identify the causes of delay for building construction projects in Egypt. Semi-structured interviews and questionnaire survey were conducted and the study identified project finaning by the contractor, owners' delay in contractor's payment, design changes as the most significant causes of delay.

2.3 *Generic delay studies*

The COVID-19 pandemic has impacted the construction projects to a significant extent. The study by Gara et al. (2022) investigated the effects of the pandemic on construction projects. The study adopted the Analytic Hierarchy Process (AHP) to prioritize the various impacts. This study found project delays, problems with the logistics, financial constraints as the top ranked impacts of the pandemic.

Rai and Sharma (2021) conducted a study to investigate the root causes of delays in Indian construction projects during the COVID-19 pandemic. The authors conducted qualitative semi-structured interviews were conducted to determine the delay causes. The study found that financial, legal and operational issues resulted in inordinate delays on the project.

Prasad & Vasugi (2017) conducted an exhaustive review of the literature on construction delay found that the nature of the causes of delay in projects executed in that of the developing countries are different from delay causes in projects executed in developed countries. In the case of developing countries, causes were largely attributed to client and contractor issues. However, in the case of developed countries, the delay causes were largely external such as unforeseen conditions, delays due to weather conditions etc.

Wong & Vimonsatit (2012) carried out a study to identify the causes of delays for projects in Western Australia. The authors identified 48 causes categorized to eight groups and adopted a Likert scale survey with a five point scale. The Five-point Likert scale was used for the questionnaire survey and RII was used to rank the responses. Shortages in skill levels, financial difficulties, and labour shortages in projects were found to be the highly ranked delay causes.

Doloi et al. (2012) conducted a study to investigate the causes of delay in Indian construction projects. A Likert scale questionnaire survey was carried out adopting 45 various delay causes for the survey. Relative Importance Index (RII) was derived based on a Likert Scale of 5 and further factors analysis of the responses was done. The study identified commitment issues, site management inefficiency, poor coordination at the site, and lack of required clarity in project scope as the most significant factors for the delay.

The findings of the literature review revealed that there has been a lot of research carried out in both developing and developed nations to investigate the causes of delay in various types of projects such as highways, buildings, etc. Largely, questionnaires have been adopted as the research instruments to identify and analyze the top causes of delay. Relative Importance Index (RII), Frequency Index (FI), and Importance Index (II) have been the most commonly used metrics to rank the causes of delay.

However, the review also revealed that there has been no study specifically investigating the root causes of delays in Metro construction projects. The present study intends to investigate the causes of delays in Indian metro constriction projects and the subsequent sections of the paper present the research methodology adopted to meet the research objective.

3 RESEARCH METHODOLOGY

The first part of the research methodology consisted of identifying the delay causes to be selected for the questionnaire. The delay causes were identified from the various research papers/literature about other types of projects/generic projects. The authors initially identified 70 causes of delays from various studies. However, on close examination, some of the causes were found to indicate the same meaning, and all such duplicate causes were removed. Finally, fifty-one different causes of delay were identified.

The causes identified also had to be put under appropriate groups. The fifty-one causes finalized for the survey were closely examined and these were categorized into six different groups. The groups are summarized below

Project-related delays – 7 causes related to direct project issues
Site-related delays – 9 causes related to site issues
Process related delays – 9 causes related to procedural/ process delays
Human related delays – 8 causes related to human skills and issues
Authority related delays – 7 causes related to issues of permissions & organization
Technical issues – 11 causes related to resources, methods, and productivity

The finalized causes and groups were put to a review through a pilot study conducted before sending out the questionnaire. The questionnaire was reviewed by a group of 5 experts two from academia and three from the construction industry each having experience of over 15 years. Based on the review, minor changes in headings and sections as recommended by the experts were incorporated.

The questionnaire was structured to four sections capture the information from the respondents. of the questionnaire sought information such as Name, qualification, and Email. The second section collected professional information such as Organization, Professional experience, designation, type of the organization (Client, contractor, consultants, etc.), and role in the project. The third section of the questionnaire sought information on the project viz., project location, project size, project type (underground/elevated), and original and anticipated dates of completion of the project.

The fourth section of the questionnaire required respondents to rate the delay causes applicable to their project on a Likert scale of 1 to 5. A rating of 1 is to be given for a cause that has not impacted/delayed the project and 5 for a cause that has significantly/severely caused delays in the project. The causes were then ranked based on the Relative Severity Index (RSI) determined as below

$$\text{Relative Severity Index (RSI)} = \sum W/(A \text{ x } N)$$

Where W is the Likert scale rating assigned by the respondents of the survey for each cause, A is the maximum rating for a cause – in this case, 5, and N is the number of respondents of the survey.

4 ANALYSIS OF DATA

The finalized questionnaire was communicated to 100 respondents seeking the participation and inputs to the research work. In aggregate, the survey received 75 valid responses (a rate of response of 75%). The authors identified clients, consultants and contractors engaged in the development of metro rail projects in India from various government tender publications and media. The authors initially adopted the snowball sampling method and sent the questionnaire to leading construction organizations in India, engaged in the construction of metro projects. The final responses received were from 39 organizations executing projects across India. The summarized information of the collected responses, the type of projects covered, and the profile of the respondents are presented in Tables 2 and 3. As it can be seen from the Tables, the responses comprised a good mix of the type of projects, size of projects. Also, more than 50% of the respondents had great than 10 years of experience, more than 80% were graduates, good mix among clients, contractors and consultants, contract type and also from varying roles.

Table 2. Distribution of responses by project type and project size.

	Project Value				
Project Type	Up to 200 Crores	> 200 Crores up to 500 Crores	> 500 Crores to 1000 Crores	> 1000 Crores	Total
Underground	1	6	2	12	21
Elevated	35	6	9	4	54
Total Responses	36	12	11	16	75
	48%	16%	15%	21%	100%

*Crores in Indian National Rupees.

Cronbach's alpha is one of the important statistical tests that checks the validity of the questionnaire survey responses and measures the reliability of the responses. The questionnaire responses were analyzed using the SPSS software version 24.

The responses of the survey can be considered to be reliable if the value of Cronbach's alpha is more than 0.7. The analysis of the response returned a value of 0.963 indicating that the survey responses were very reliable.

The group of respondents had a mix of professionals from consultants, contractors, and clients, and traditionally, these groups of respondents have dissimilar opinions and often conflicting views about a particular observation. It was very essential to also assess the responses from these different groups of respondents.

Table 3. Profile of the respondents.

Characteristics	Number of responses	% of Total
Role		
Clients	18	24%
Contractors	23	31%
Consultants, designers & others	34	45%
Experience		
Up to 5 years	27	36%
5 years to 10 years	15	20%
10 years to 20 years	21	28%
More than 20 years	12	16%
Educational Qualifications		
Diploma	12	16%
Undergraduate	35	47%
Postgraduate	28	37%
Contract Type		
Item Rate	19	25%
EPC	56	75%
Role in the Project		
Engineering/design	26	35%
Project planning & control	33	44%
Site execution	11	15%
Contracts	5	6%

For this purpose, the One-Way Analysis Of Variance (ANOVA) test was conducted at a 95% confidence level. ANOVA test has been used by previous studies on delay causes [Prasad et al. 2019a, Prasad et al. 2019b, Wanjari & Dobariya, 2016, and Marzouk et al. 2014) and is found to be effective in understanding the agreement levels and perception differences among different groups of respondents. The delay causes and the results of the ANOVA test are summarized in Table 4.

The results of the ANOVA test indicate that out of a possible 51 causes, 35 cases (70%) of them have no significant statistical difference, which indicates that all the group of respondents -contractors, clients and consultants agree on the delay causes.

5 RESULTS AND DISCUSSION

Results of the study with the top ten causes of delay in Indian metro projects are summarized in Table 5. Permission from local authorities, change in material prices, change in government laws and regulations, poor labour productivity, poor coordination among parties, Non availability of operators with skills for specialized equipment, financial constraints of contractors, the conflict between owners and other parties, subcontractors frequently getting changed on the project and improper bid stage planning by the contractor were found to be the top causes of delay in Indian metro construction projects. The authors can share the complete set of results and the ranking of the delay causes if it is of specific interest of any of reader/authors from the research community. The top ten delay causes with their RSI are summarized in Table 5. The top five causes are discussed.

Metro projects because of their nature of work require numerous permissions from local authorities of various nature. Because of their linear characteristic and that the projects are usually constructed in the urban environment, often these require permissions to divert various utilities viz., underground water services, sewerage pipelines, overhead electrical lines, traffic diversion permissions, etc. Each of the authorities has its own procedure and process to get the required permission. In addition to this, there can be additional utilities that may be

Table 4. One-Way ANOVA test results with delay categories, & causes of delay.

Delay category	Cause of delay	Significance at 95% confidence level
Project related delays	Increase in the work scope	0.640
	Lack of clarity in contractual specifications and conflicting interpretations	0.893
	Inaccurate reports on soil/ground investigations	0.417
	Rework due to change in decision/deviation order	0.009*
	Unrealistic time schedule mandated in the contract	0.167
	Non-availability designs and drawings on time	0.002*
	Rework due to errors during work execution	0.107
Site related delays	Restricted Site Access	0.000*
	Extreme Weather Conditions	0.062
	Owners' slow process of decision making	0.055
	Vendors' delay in delivery of material	0.063
	Negligent work practices leading to accidents on site	0.773
	Accidents on site due to lack of adequate measures for safety	0.958
	Unforeseen ground conditions	0.001*
Process Related Delays	Delay in supply of materials by the owner	0.464
	Owner's delay in completed work's approval	0.003*
	Contractor's delay in procurement of the materials for the project	0.114
	Delay in approval of drawings and samples	0.000*
	Owner's delay in running bill payments to the contractor	0.056
	Site handing over delays	0.000*
	Delay in finalization of rates for extra items	0.002*
	Damage of the materials on site due to improper storage	0.300
	Improvisation of drawings and instructions/inputs	0.027*
Human Related Delays	Architect or consultant's reluctances for change	0.078
	Poor site supervision and management	0.092
	The conflict between owners and other parties	0.045*
	Non-availability of operators with skills for specialized equipment	0.875
	Weak coordination between parties to the contract	0.113
	Subcontractors frequently getting changed on the project	0.116
	Labour safety and health issues	0.645
	High labor wages	0.896
Authority Related Delays	Local authorities' permission for the project/works	0.004*
	Bureaucratic work culture at client's organization	0.099
	Consultant's/client's poor organization culture	0.137
	Changes in government policies, laws and regulations	0.723
	Inadequate subcontractor control	0.673
	Inappropriate contracting strategy	0.516
	Improper project performance monitoring	0.483
Technical Issues	Absence of adequate motivation for contractors to complete projects early	0.072
	Improper bid stage planning by the contractor	0.275
	Contractors' constraints with finances	0.002*
	Poor labor productivity	0.090
	Contractors' lack of adequate experience	0.642
	Escalation in the prices/changes in the prices of materials	0.001*
	Equipment being put to inefficient usage/deployment	0.004*
	Deployment of improper or obsolete construction methods	0.728
	Unrealistic inspection and testing methods proposed in the contract	0.381
	Delayed site inspections	0.013*

* Indicates that the difference in perception is significant at a 95% confidence level

Table 5. Top ten delay causes in Indian Metro Projects.

Cause of delay	Relative Severity Index (RSI)
Local authorities' permission for the project/works	0.637
Escalation in the prices/changes in the prices of materials	0.605
Changes in government policies, laws and regulations	0.595
Poor labor productivity	0.595
Weak coordination between parties to the contract	0.592
Non-availability of operators with skills for specialized equipment	0.589
Financial constraints of contractors	0.581
The Conflict between owners and other parties	0.579
Subcontractors frequently getting changed on the project	0.573
Improper bid stage planning by the contractor	0.573

discovered during the execution of the works which may again need further permissions. Hence, this can be one of the significant hindrances [Gopang et al. 2020, Vilventhan & Kalidindi, 2016 and Abhyankar et al. 2017) for the project.

Typically, most metro projects involve various imported materials viz., bearings, adhesive compounds, curing compounds for the segments, pre-stressing materials, and accessories all of which are highly specialized in nature and customized to the project requirements (IUT, 2021) Because of the high demand for these materials due to the increasing number of metro projects, the price of these materials may vary with the demand and also the inventory available with the manufacturers. Advanced planning and timely order placement can help contractors negate the impact of material price escalations.

Changes in government regulations are found to be the third most rated cause of delay in Indian projects. This could be attributable to the fact that metro projects require many customized components including key electromechanical components, components related to HVAC, Firefighting, plumbing which are highly customized and subject to price sensitivity. In the last three years, there have been many policy changes by the Government of India due to the introduction of the GST (Chavan et al. 2019, PWC, 2019), and this has impacted the revenue and cost of all projects and reflects in the ranking of the causes of delay.

Metro projects require utmost precision, careful planning, and execution of works meticulously. The projects require skilled labour (Sharma et al. 2013, Abdel-Hamid & Abdelhaleem, 2020) to comply with stringent quality specifications and tolerances. The productivity of the workers is an important factor that plays a crucial role in the timely completion of projects. In our country, the availability of trained manpower is very scarce and also seasonal. Every time, there is a change in the season or gang of labourers, the work speed, the rhythm gets disturbed and this also leads to loss of productivity and can lead to significant delays in the project.

Metro projects are awarded in many packages usually to different contractors. Within the same package also there can be many different multidiscipline contracts viz., civil works, electromechanical works, track works, signaling systems, etc. This means a lot of coordination effort needs to be maintained between the contractors of different packages and also the concerned client officials of these different packages. There can be many interrelated works among these different parties and poor coordination (Pucher et al. 2004) among any of these parties can impact and delay the works of other parties.

6 CONCLUSIONS

The present study has attempted to investigate the major causes of delays in Indian metro projects. Through the questionnaire survey of professionals working in the Indian metro projects, the study has found that permission from local authorities, change in material prices, change in government laws and regulations, poor labour productivity, poor coordination among parties, lack of skilled operators for specialized equipment, financial constraints of contractors, the conflict between the owner and other parties, frequent change of sub-contractors and improper planning by the contractor as the top causes of delay for construction of metro projects in India.

The present study can further be expanded with more responses from the underground metro works and a meaningful comparison can also be made to compare the causes of delay between that of elevated metro projects and that of underground metro projects. In addition, a comparison can also be made between the causes of delay in different contract types viz., Item rate and EPC projects. The comparison can also be drawn by investigating the causes of delay on projects of different contract value ranges.

Further, the results of this study can be shared with the industry professionals and appropriate measures to mitigate the high ranked delay causes can be identified which can help in minimizing the delay on metro projects.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)

Challenges in urban road maintenance in Sub-Saharan Africa: A scoping review and thematic analysis

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ABSTRACT: Road infrastructure is the backbone of sustainable development of any country. To keep road infrastructure in good condition, proper and timely urban road maintenance should be carried out. However, proper and timely urban road maintenance is constrained by several factors including funding mechanisms, contractors' capacity, procurement processes, and force majeure. This paper, therefore, presents detailed findings on factors impacting urban road maintenance in Sub-Saharan Africa (SSA) based on review of peer-reviewed papers with focus on SSA. In addition, reports on infrastructure investment in SSA published by international organizations and Africa Development Bank were also reviewed. The findings reveal that funding mechanisms and force majeure are critical factors that influence urban road maintenance management. This research will augment knowledge of urban road infrastructure experts from some developing countries who have not carried out detailed research in this area by providing information on the factors to be considered in urban road maintenance.

Keywords: Urban roads, Maintenance, factors, Sub-Saharan Africa

1 INTRODUCTION

Road infrastructure is the backbone of sustainable development of any country. Worldwide there is a solid, constant, and direct relationship between road development and economic development (Messik, 2011). A well-maintained road network will reduce travel time and this leads to a reduction in the cost of doing business and increase economic productivity. Urban road maintenance has been a very critical problem in many African countries. About $30 billion is annually lost worldwide due to insufficient urban road maintenance (Messik, 2011). Poor condition of road infrastructure has been an obstacle to Sub-Saharan Africa (SSA) from advancing from its current economic status into an industrial economy (Gbahabo & Ajuwon, 2017). It is important therefore that Sub-Saharan Africa works out on how to improve its infrastructure.

Therefore, this paper attempt to analyse these factors based on review of literature. The paper presentation format has five sections which are introduction, materials and methods, understanding of the factors impacting on urban road maintenance, conclusion and recommendation.

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2 MATERIALS AND METHODS

This study involved a scoping review of secondary data, whereby different literature on urban road maintenance from Sub-Saharan Africa was reviewed. The thematic analysis method was used in data analysis because it is very useful when different topics are involved. Also, it is flexible in data reduction to bring a meaningful description to data presentation (Castleberry & Nolen, 2018). This paper has involved a wide range of literature reviews which included 23 peer-reviewed papers which are from different parts of Sub-Saharan Africa such as Southern Africa, Western Africa, Eastern Africa, Northern-East Africa and Central Africa. In addition, reports on infrastructure investment in SSA published by international organizations and Africa Development Bank (AfDB) were also reviewed.

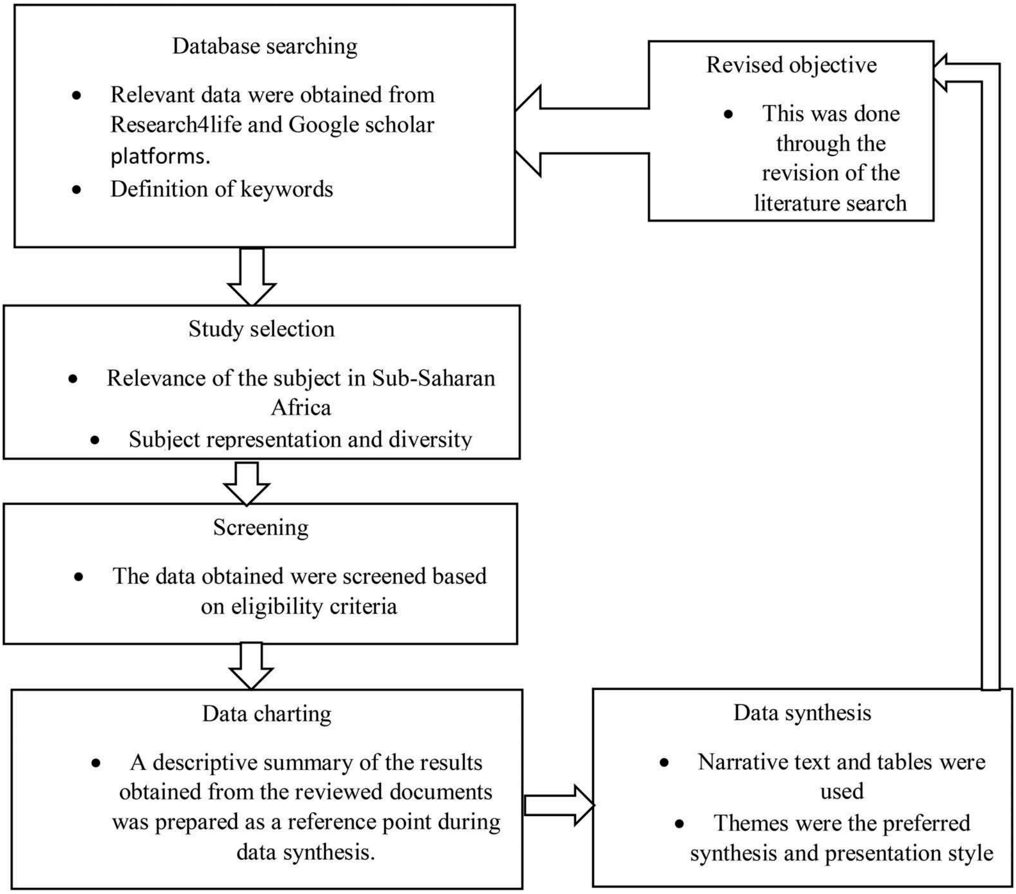

Figure 1. Scoping review flow and analysis.

Firstly, relevant published materials were obtained from Research4life and Google scholar platforms which are among the trusted internet search engines for the academic materials. However, the keywords that were used in searching for the required information were urban road, maintenance, factors and Sub-Saharan Africa.

Secondly, there was the study selection which was done by considering the relevance of the study as well as the representativeness of the literature considered during the review and their diversity.

Thirdly, the screening was purposely used to filter the literature obtained from the search engines by considering the eligible literature that were fitting in a study in order to obtain the intended results.

Fourthly, data charting was all about extraction of the information from the obtained literature, this was associated with creation of summary that was useful during the synthesis process.

Fifth, data synthesis was the section that dealt with the analysis of data and presentation whereby it involved the produce of the narrative texts and tables as well as themes which were the preferred presentation style in this paper.

Sixth, revised objective, is the procedure that involved the cross-checking with the paper objective in order to be assured of what is going on, if the researchers were in the right track or not.

3 UNDERSTANDING FACTORS THAT IMPACT ON URBAN ROAD MAINTENANCE

In many areas, urban road maintenance has been facing several challenges which have led to the worsening of the road conditions. In SSA the situation is even worst compared to the rest of the world due to four main factors which include the following: funding mechanism of urban road maintenance, contractors' capacity, procurement process, and force majeure. These are discussed below:

3.1 *Funding mechanism of urban road maintenance*

Different countries adopt different funding models for urban road maintenance programs. Mostly highlighted models include: Road fund from road user charges, Public-Private Partnerships (PPP), and Funds from Central and Local Government, follow up sections will demonstrate how these funding mechanisms influence urban road maintenance programs.

3.1.1 *Roads fund*

Many sub-Saharan African (SSA) countries for example Ethiopia, Tanzania, and Malawi adopted the establishment of Roads Fund (RF) which has the purpose of raising funds for urban road maintenance within countries. (Hassan, 2018). South Africa, Nigeria and Senegal have road agencies that manage road maintenance (Gwilliam et al., 2008; Hassan, 2018). However, funds collected through road user charges such as fuel levies and taxes from vehicles' spare parts have not been sufficient to cater to the need of urban road maintenance in many developing countries. This is because the set charges are too low and sometimes difficult to collect, hence the need for central governments' support on their deficit (AfDB, 2011; Gwilliam et al., 2008).

In addition, Roads Fund Boards need clear legal foundation, separation of functions, clear revenue allocation rules and independent auditing accounts (Gwilliam et al., 2008). This will enable avoidance of the bureaucracy in the collection of the funds as well as in decision making. Moreover, ringfencing of RF has been hardly adopted by many SSA countries and there has been skewness against routine maintenance spending (Streatfeild, 2019).

3.1.2 *Public-Private Partnerships (PPP)*

According to (Mgalla, 2015) PPP is a growing infrastructure provision model and funding mechanism in many countries especially developing countries. It is an unavoidable option for most of the Sub-Sharan African countries since they have a deficient infrastructure budget. For example Kenyan government has opted for PPP as the way to reduce the burden and gap of financing the road sector ((Kamau, 2016). Due to poor legal, institutional and regulatory frameworks and arrangements, Zambia has failed to exhaust the full potential of PPP and it has been experiencing failures in many projects (Muleya et al., 2020). Tanzania government opted for the Improve, Finance, Maintain, Operate, Transfer (IFMOT) form of PPP due to the existing maintenance funding gap

(Mgalla, 2015). Meanwhile, in Ethiopia the adoption of PPP was influenced by the need to encourage rapid economic growth considering that the PPP saves time and adhere to quality standards of infrastructure compared to traditional procurement method (Debela, 2022). Similarly, in Ghana the PPP has been a preferred urban road maintenance funding mechanism, in which the construction is within the agreed concession period to avoid delays (Osei-Kyei & Chan, 2018). However, this entails that PPP is the better choice to many countries especially when terms and conditions are well understood between public and private sector for the broad interest of the public especially in road sector.

3.1.3 *Funds from Central and Local government*

Many researchers have underscored the influence of funding on urban road maintenance activities for example, in Nigeria, it was found that budget deficit due to inconsistence funding and poor information flow have led to misallocation of funds and mismatch between financial requirement and deterioration (Hassan, 2018; Yoade et al., 2022). Angola government has been spending about $ 4.3 billion annually for road reconstruction due to the destruction caused by war (Benmaamar et al., 2020; Hassan, 2018). According to the studies made, it is portrayed that most local governments cannot finance urban road maintenance from the internal revenues such service charges, fines and penalties instead they depend on the central governments which have many responsibilities to work on.

3.2 *Contractors' capacity*

Contactor's capacity can be in form of Capital (equipment or liquidity) and/or Human resource. Many contractors fail to manage urban road maintenance due to lack of capital or technical expertise. Urban road maintenance programs are often times affected by these constraints.

3.2.1 *Capital constraints*

Many countries have been practicing the traditional procurement processes whereby urban road maintenance and rehabilitation have been done by the local contractors. However, these contractors have been facing a number of challenges. For instance, in Malawi and Tanzania, most of entrusted indigenous contractors are economically unstable, they lack a financial capacity to manage different road projects (Kulemeka et al., 2015; Ye & Tekka, 2020). However, contracts are offered to the small and medium contractors (SMCs) though with limited financial capacity in order to support their growth which is measured by their performance through the contracts they are given. In Tanzania, finance and technology constraints have negatively impacted the SMCs (Ye & Tekka, 2020). The financial constraints extend from management skills, inaccessibility of loans, high interest rates, cash-flow problems, shortage of technical and competent human resource and lack of advanced equipment, limited skills in information and technology. Indeed, it is impossible for SMCs to grow and become competent in their deliverables if there is poor climate to support them financially. As such, in order to improve capacity of the SMCs, thereby improving the urban road maintenance in developing countries governments must create a conducive climate for the financial institutions and contractors to work in harmony.

3.2.2 *Human resource*

The need for competent human resource in any project need not be overemphasized. Committed management backed up by the sufficient information flow and communication channels and competent staff is a backbone to any successful project (Densford et al., 2018; OECD, 2007). Lack of trained manpower has an adverse impact in project management. For example in Tanzania, Kyela to Mbeya road project was subjected to time overrun as well as cost overrun due to lack of competent key personnel. Kerzner (2017) also noted that knowledge on the project monitoring and evaluation is lacking in many developing countries. Moreover, according to Ye & Tekka (2020) lack of exposure to the human resource lead to inexperience and inadequate strategic management on the part of many contractors in developing countries. Therefore, contractors to be engaged in the maintenance of urban roads should have competent employees who should endeavor in continued development of their profession.

3.3 *Procurement processes*

Procurement processes are all processes that are involved in tender bidding whereby tender are advertised by the public or government entities to call for the competition among the contractors who come with different offers. However, most tenders have been affected by the governance systems as follows.

3.3.1 *Governance*

In Sub-Saharan Africa, there has been high corruption in the procurement process which has led to very high maintenance costs (Beuran et al., 2015). Ogbu & Asuquo (2018) also noted that in many countries corruption and other unethical practices occur during tendering process. Purposeful overestimation has been observed through road authorities and anticorruption commissions together with auditors (Beuran et al., 2015). In 2011, Tanzania had an overestimation of about 60% which was very high (Messik, 2011). Likewise, Beuran et al., 2015 underscored the presence of procurement and construction practices that opened the doors for corruption in Kenya and Zambia. This entails that for a successful urban road maintenance programme there is need to have a good governance in the procuring processes of the contracts.

3.4 *Force majeure*

Force majeure are the factors that are unpredictable and most of time are out of human reach, and they come unexpectedly. These factors can only be adapted and not controlled and climate is the one those factors which affect the urban road infrastructure due to its extremes.

3.4.1 *Climate*

According to the study that was made in countries that are located along the Zambezi River basin, climate seemed to be the challenge in urban road infrastructure maintenance. This is because the climate change has affected construction costs especially in maintenance and rehabilitation (Strzepek & Strzepek, 2015). Mozambique being at the end of several transnational river basins, it is often subjected to the floods which cause most of its installed infrastructure to be vulnerable to the weather extremes (Arndt et al., 2012). This has resulted into the increase in maintenance needs due to the limited capacity of the current road network to withstand the climate (Chinowsky & Arndt, 2012). As such, there has been a challenge in improving the road sector in Mozambique regardless of 15% of government expenditure on road infrastructure. Therefore, it is worth to incorporate the design standard evolution in responding to climate change instead of relying on the reactive approach which comes after the effects.

A summary of themes and subthemes that were considered in this review are demonstrated in Table 1.

Table 1. Summary of themes and subthemes.

Theme	Subtheme	Citation
Fund mechanism of urban road maintenance	Roads fund	(Gwilliam et al., 2008; Hassan, 2018; Streatfeild, 2019)
	Public-Private Partnerships	(Kamau, 2016; Mgalla, 2015; Muleya et al., 2020)
	Funds from Central and Local government	(Benmaamar et al., 2020; Hassan, 2018; Yoade et al., 2022)
Contractors' capacity	Capital constraints	(Kulemeka et al., 2015; Ye & Tekka, 2020)
	Human resources	(Densford et al., 2018; Kerzner, 2017; OECD, 2007)
Procurement process	Governance	(Beuran et al., 2015; Messik, 2011; Ogbu & Asuquo, 2018)
Force majeure	Climate	(Arndt et al., 2012; Chinowsky & Arndt, 2012; Strzepek & Strzepek, 2015)

4 CONCLUSION

This review has uncovered that most of the problems facing SSA on issues of urban road maintenance can mainly be attributed to four major factors which are funding mechanisms of urban road maintenance, contractors' capacity, procurement processes and force majeure. However, the findings reveal that funding mechanisms of urban road maintenance and force majeure are critical factors and need to be considered during planning and execution of urban road maintenance programs. Therefore, it may be suggested that if these factors are addressed there might be positive significant shift on management of urban road maintenance activities in SSA countries, thereby positively influencing the economic growth of Sub-Saharan African region.

With good road infrastructure, the cost of transportation of goods for example raw materials will reduce, as such, it will be easy for countries to attract investments since most of African countries have raw materials. Therefore, Africa continent especially SSA only need a revolution in the management of its infrastructure sector and roads in particular for it to advance economically.

5 RECOMMENDATION

It is recommended that for the urban road maintenance to be successful in Sub-Saharan Africa, the SSA governments have to create a conducive environment of working with PPP especially involving local investors because this can reduce the governments' burden of financing urban roads maintenance. This arrangement also enables sharing of risk in road projects which involve huge investments. This can be successful and fully enjoyed through the reformation of legal, institutional and regulatory frameworks and arrangements that support the PPP within favorable and balanced terms and condition between private and public entities.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Exploring the viability of green building to raise green bonds in the South African property market

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ABSTRACT: The study examined the viability of using green bonds as an alternative financial instrument for green buildings in order to improve its application for property development in South Africa. The study used a qualitative approach of structured interviews to collect data from construction professionals who were purposively selected. The key finding is that corporate firms are not satisfied with the amount of work involved with the data collection required to raise green bonds and the interest rate that is charged on the bond. The study concludes that corporate companies are reluctant to use green bonds as a financial instrument because of the high-interest rate. Owing to the high interest rate on bonds, the study recommends that more financial institutions should invest in green bonds, so that the market can be competitive with numerous investors in the market.

Keywords: property market, green bonds, green building, sustainability, viability

1 INTRODUCTION

The construction sector plays a significant role in the economy through its contribution to the gross domestic product, employment opportunities and development of infrastructure. However, construction is also viewed as a wasteful sector as it consumes most of the natural resources for its activities and produces a lot of waste during renovation, demolition and construction activities (Skitmore et al., 2019). In recent years, the negative effects of construction activities have raised increased concern and a move toward adopting sustainable construction practices including green building (Akadiri et al., 2012). This study explores the viability of increasing the green building stock through green bonds in the South African property market.

Sustainability is a concept driven by three main pillars namely economic, environmental and social factors. As part of sustainability, green building is both a process and a product (building) that uses renewable resources for the construction of buildings that are energy-efficient, durable and resource-conserving. Green building is used in this study as a subcategory of a green portfolio, which is known to be an eco-friendly investment field. Several studies have highlighted that green building has many benefits such as increased productivity and health, lower operating costs, enhanced marketability, high market value and climate change combating. However, there have also been several challenges or barriers associated with the implementation of green buildings in the literature. Efforts of implementing sustainable construction have fallen short in some countries as a result of various barriers (Ametepey et al., 2015).

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While most studies have highlighted the high costs associated with green buildings as one of the main barriers (Darko et al., 2018), the concepts of green bonds and green portfolios have emerged in recent years to mitigate the challenges of financing green buildings. Extant studies have submitted that the green bond market is a potential source of climate finance for developing countries. The financial intellect and innovation of the green bond market can support society under specific conditions (Paranque & Revelli, 2017). Green bonds provide infrastructure finance opportunities that are sustainably long-term (Kaminker et al., 2018) and feasible and can allow municipalities to explore and undertake climate-resilient projects (ESI Africa, 2018).

In many developing countries, the green bond market remains underdeveloped with its full potential being inadequately appreciated (International Finance Corporation, 2019). Paranque & Revelli (2017) contrast green bonds with conventional bonds issue and indicate the difference to be associated with the environmental impact as anticipated by the investment. However, green bonds and conventional bonds are similar regarding structure, return and risk profile where the fixed-income market is concerned, with a correlation of yield to maturity of both bonds (Banga, 2018). Though there was initial hesitancy by investors regarding green bonds, recent trends suggest that there has been an increasing awareness among traditional investors regarding the payback period of green investments, and the possible climate effects which they may have on financial assets. Understanding the possible links between financial stability and climate change is one of the factors that encourage an increase in the green bond market.

In developing countries of Africa, there is rarely any assessment of the environment, regarding buildings, in relation to their carbon emissions and the energy they consume (Kibwami and Tutesigensi, 2016). As a result, the only time stakeholders use green alternatives is if they are financially feasible and viable; provided there is an exceptional prerequisite to abide by the green building rating system (Darko et al., 2017). This is because the majority of green building actions and decisions in the construction industry are based on financial returns. A significant number of organizations and stakeholders do put in the effort to adopt green building processes as a reaction to the improvement of their image and corporate culture, the necessity of energy conservation, response to customer demand, improvement of marketability, and lower maintenance and operating costs. ESI Africa (2018) noted that several projects have been financed by green bonds in South Africa to influence investors on the need to finance similar ecological projects. Ametepey et al. (2015) listed some barriers to sustainable construction, and these include financial barriers. The adoption of green bonds could thus be seen as a means of addressing the challenges posed by conventional funding sources for green projects. Green bonds have become known to be categorized as one of the best debt financial instruments to mobilize financial resources for sustainable development. It is expected that the use of green bonds will foster the construction of sustainable buildings, which satisfy green star ratings and help keep a record of sustainable buildings and their ratings

Thus, the study aims to examine the viability of using green bonds as an alternative financial instrument for green building to improve its application in property development in South Africa. Specifically, the study assessed the level of awareness of green bonds among construction professionals, evaluated the viability of green bonds as a financial instrument and assessed the requirements and constraints of green bonds. In addition, the study also analysed the benefits and advantages of green bonds in comparison with other financial instruments.

2 LITERATURE REVIEW

2.1 *Green building*

Sustainable construction includes activities such as tendering, material selection, waste minimization, recycling, site organization and planning and requires all activity members to work towards the same goal of being sustainable (Ametepey et al., 2015). Green buildings are the first phase of the introduction of sustainability and are thought of as a subcategory of sustainable development (Zuo and Zhao, 2014). The green building concept introduced numerous improvements to former concepts such as using more eco-friendly resources and materials and applying eco-friendly practices to reduce waste and consumption while also saving resources, to mitigate the effects of Carbon dioxide emissions.

The concept of sustainable construction was introduced predominantly in developed countries and less adopted in developing countries (Elmualim and Alp, 2016). Efforts of implementing sustainable construction have fallen short in some countries as a result of some barriers (Elmualim and Alp, 2016). A study by Ametepey et al. (2015) found that the barriers to raising green bonds are the government's lack of commitment, high interest on green bonds (Banga, 2018), and resistance to cultural change respectively. These barriers are categorized as follows; leadership/management barriers, technical barriers, financial barriers, political barriers, socio-cultural barriers, and awareness/knowledge barriers. Furthermore, Chan, Darko and Ameyaw (2017) suggest that there should be funding devoted to the development of sustainable construction to create awareness, provide economic incentives, and undertake training and seminars workshops by stakeholders.

2.2 *Green building benefits*

The benefits of green building are enumerated in extant literature. For instance, GBCSA, (2019) noted that green buildings save between 25 to 50 per cent more energy than conventional buildings. Also, green building designs play a crucial role in that they counteract climate change to create an environment that is suitable for the community (Bassi et al., 2017). Green buildings have characteristics that promote the value of the buildings and include their competitiveness in the market, low costs of operation and lease premiums which make them future-proofed low-risk buildings (Grobler, 2016). These factors have been shown to play a big part in the Australian and American valuation of premiums both being at 12 and 11 per cent respectively (Grobler, 2016). Rental rates of green buildings are also higher compared to conventional buildings, as seen in Australia with an increase of 5% and the United States of America with an increase of 6% (GBCSA, 2019). Other benefits as noted by Darko, Owusu, Antwi-Afari, and Chan (2018) include reduced lifecycle costs, enhanced occupants' health and comfort, improved overall productivity and environmental protection.

2.3 *Incentive system*

Incentive awards as drivers for stakeholders, for the implementation of green construction, promote green building processes in that they recompense stakeholders for additional costs that may be necessary to build green (Darko et al., 2017). Incentives are grouped in terms of how they motivate. They can either be external or internal incentives. While external incentives can be further categorized into financial or non-financial incentives. Internal incentives are rewarded as a result of goodwill (Olubunmi et al., 2016). Financial incentives comprise rebates, tax incentives, and discounted development claim fees; whereas non-financial incentives consist of technical assistance, business planning assistance and devoted green administration teams in planning and building departments (Olubunmi et al., 2016). Olubunmi et al. (2016) noted that these incentives have been found to trigger a rapid green building growth rate in developed economies.

The government is responsible for the administration of external incentives that play a role in the choice to meet specific green building requirements or conditions (Olubunmi et al., 2016). Government intervention and globalisation are other important factors that drive the incorporation of green strategies in the construction industry (Kylili and Fokaides, 2017). Olubunmi et al., (2016) suggest that the private sector plays a leading role, ahead of the government in being the provider of green building incentives, because of the force of the private sector.

2.4 *The cost of building green*

Property developers in South Africa are primarily concerned with sustainable buildings being financially viable (Infrastructure news, 2019). At first encounter, the extra work and substitute materials needed for green buildings may seem like a steep cost to incur but looking further into detail, it can be discovered that building green is after all not so burdensome financially (Knox, 2019). There is a green premium incurred by green buildings over the costs of conventional construction but despite the premium, green buildings offer a variety of environmental and monetary advantages that conventional buildings do not. Coetzee and Brent (2015) state that there are studies conducted on the cost premium of implementing green buildings versus the saved costs through the life cycle of the building which found that the marketplace does have the perception that cost premiums are higher than the research shows.

Considering the operational, energy and maintenance improvements as part of the entire process, long-term savings as a result of the improvements balance the extra costs incurred by green buildings (Knox, 2019). As argued by Runde and Thoyre, (2010), when young green building markets mature and the practices and materials become widespread, the new green building market premiums will decline and the cost at which green building is exercised will be similar to that of conventional buildings. For a better understanding of the construction industry's perception, Ahn and Pearce (2007) did a survey and found that thirty-five per cent of respondents thought green building cost premium ranges from five per cent to about ten per cent, twenty-seven per cent thought the cost premium is more than ten per cent and thirty-eight per cent thought it is between zero to five per cent. These responses show that a part of the construction industry still hold the belief that the cost premium of green building is significantly higher than conventional buildings, notwithstanding the opposing body of evidence that is still growing (Ahn and Pearce, 2007).

Looking at other countries, Infrastructure news (2019) found that most premiums reported in the United States of America are in the zero to five per cent range. The difference in cost of investing in green buildings is insignificant compared to investing in similar conventional buildings, and in comparison, green buildings accomplish higher investment returns with better property valuations.

2.5 *Green bonds*

Zerbib (2017) defines green bond premium as the yield difference between a conventional bond and an equivalent green bond. The key difference between green bonds and conventional bonds is that the proceeds should specifically be invested in projects which are eco-friendly and produce environmental benefits (United Nations Development Programme, 2019).

Karpf and Mandel (2017) investigated the green bond yields in connection with conventional bond yields and the investigation indicated a positive 7.8 Basis points (bps) for green premium in the green bond market fragment. Litvinovs and Raiko (2017) found opinions that suggest that big institutional investors tend to hold green bonds until they mature under the impression that this means the green bonds will be less volatile on the secondary market, making this potentially the reason for their low yield spread. Zerbib (2017) suggests that fiscal and regulatory policies could assist in creating incentives for increasing the issuance volume of green bonds.

United Nations Development Programme (2019) further explains the green bond process in its simplest form, that the juridical person issuing the bond will raise a determined amount of capital, and repay the principal capital plus the interest added for a pre-set period. Green bonds are a lucrative opportunity for the party that is issuing them because unlike conventional bonds they are oversubscribed and for this reason they offer better terms (CNBC, 2018). Green bonds are more stable and less volatile on the secondary market because there is an increased demand which means that investors only pay a small premium for growing stability (Litvinovs and Raiko, 2017).

Summarily, extant studies have suggested that conventional construction methods are harmful to the environment and thus alternative means of construction are necessary. Green building is presented by various authors as an alternative way of construction that will be less harmful to the environment. However, among the challenges, the raising of funds for green buildings through the use of green bonds has not been fully explored for the development of green buildings. Thus, if the green bonds financing mechanism is successfully implemented, it might be expected to translate into an increased stock of green buildings.

3 DATA AND METHODS

The study focused on the perception of South African construction professionals who are familiar with green buildings and green bonds in South Africa. The study adopted a qualitative research approach. Purposive sampling was used to identify the respondents and structured interviews were conducted with professionals who have been involved in the construction of the green building and utilizing green bonds. In particular, the snowballing technique was used, as the researcher had to rely on the respondents to refer other professionals to be interviewed. This owes to the fact that the study requires information from knowledgeable respondents. Thus, interviewees with at least two years of experience in green buildings and green bonds in South Africa were selected to participate in the study. These professionals shared their knowledge based on their experience and their professional opinion on using green bonds for green building.

The target population for this research study is primarily the professional team involved in green building in South Africa. Towards this end, the interview involved construction professionals namely Quantity Surveyor(s), Architect(s), Engineer(s) and members of the finance department of corporate companies in South Africa. Due to the low number of green building projects done in South Africa, the number of professionals involved first-hand in a green building project is low. There is no list of people who have participated in green building and green buildings to provide a thorough sampling framework. However, the green building council of SA was used as a starting point for locating respondents who were interested in participating in the study.

In qualitative research, sample sizes are established based on theoretical saturation. The saturation point is the point in data collection when further data collection no longer brings in new insight to the research questions (Mason, 2010). The saturation point for the interviews was reached at the eighth interview. Subsequently, the responses were thematically analysed.

The profile of the respondents shows an equal number of representations for Architects (25%), Quantity Surveyors (25%) and finance professionals (25%). Whereas Construction Managers accounted for 12.5%, and those who indicated others were 12.5%. The result also shows that majority of the interviewees (75.00%) had at least five years of working experience. The findings suggest that the respondents are knowledgeable enough to add value to the study. Summarily, the respondents' profile shows that there was a variety of professionals with different knowledge levels and from different professional backgrounds.

4 DATA PRESENTATION

The respondents were asked questions ranging from awareness of green bonds, the viability of green bonds, requirements and constraints to the adoption of green bonds as well as the benefits of green bonds in comparison to other financial instruments.

4.1 *Green bond awareness*

The interviewees indicated several ways that the construction industry can increase the awareness of using green bonds in South Africa. The responses are presented below

> *Respondent 1:* "Awareness can be created by corporate companies that have issued green bonds, the Johannesburg stock exchange, . . ., financial institutions can create awareness making use of the magazines' websites and other platforms they use to advertise their products". *Respondent 2:* "Bondholders and other financial institution that invest in green bonds should create awareness through communication with their clients indicating green bond as other financial instruments they offer. These institutions should also have pamphlets in their office buildings educating about the availability and use of green bonds. Even though green bonds are only available to big corporate companies if more corporate companies are aware of it and they can plan for it, and make use of it when

they are in a position to do so". *Respondent 4:* "Institutional Investors and the Green Building Council of South Africa should ensure that information regarding green bonds is published in the relevant construction newspapers and magazine articles". *Respondent 7:* "Annual conferences, business dialogues and workshops are effective ways of creating awareness".

It was found that green bond awareness is created by institutions and development companies through their product and achievement marketing platforms such as websites, leaflets, and newsletters. Awareness is also created through annual conferences, business dialogues, workshops, and hopefully, this can also be achieved through the criteria of the environmental, social, and governance (ESG) mandate on the investor's side. The media can also play a role in creating awareness through hardcopy and online newspaper and magazine articles.

4.2 *The viability of green bond as a financial instrument*

The interviewees were asked about the viability of green bonds as a financial instrument to develop green buildings. The responses showed that there was a consensus that green bonds were viable as they provide financing for green projects. The responses are presented below:

Respondent 1: "Green bonds are viable in the sense that they did provide finance for the development of green projects". *Respondent 2:* The viability comes from the fact that the green bonds promote and make the development of green building possible". *Respondent 6:* "The construction industry is aiming to become an environmentally friendly industry, and the ability of the green bonds to drive the encouragement of green buildings, makes it a viable financial instrument". *Respondent 4:* "Green bonds drive companies to meet the need to be sustainable.

The findings show that green bonds are viable financing tools for green building. Green buildings are usually estimated at high costs, green bonds can conveniently cater for these high costs for these buildings. Hence, the availability of funds for the successful construction of the green buildings will therefore not be a problem. The existence of green bonds intends to promote green building and drive corporate companies to invest in sustainable development. Therefore, this raises the viability of green bonds to finance green buildings.

4.3 *Green bond requirements*

The interviewees were asked what the main requirements for raising green bonds were. The responses showed that the main requirement was being able to demonstrate evidence of ability to repay a loan mainly through debt history or meeting all the debt requirements. This is reflected by the following responses:

Respondent 1: "When borrowing money, you need to have a debt history that is in line with the amount you are lending. So, for a green bond, you need to be able to have a debt programme that allows you to borrow from a hundred million to a billion. The project to be funded must be a green project and proof of that must also be provided. Security must be provided for the amount being borrowed." *Respondent 2:* "The JSE provides the requirements in the 'debt listing requirements' document and, those are the requirements that need to be met. Furthermore, the investor may have additional requirements such as providing proof that the building is as green as it was said to be when the bond was issued". *Respondent 3:* "Provide the ability to repay the loan, use of proceeds for green building and show that the building is green".

In terms of accessibility, it was highlighted that access to green bonds is only available to big firms, not small ones:

Respondent 4: "Green bonds are only available to big corporate companies, as they require a company to be able to borrow a minimum of one billion rands. Once you have a company that can borrow a billion rand you would put your bond programme in place the terms and conditions in place and make an arrangement with trade. You will need to adhere to the debt listing requirements that are set out by the JSE similar to the requirements".

The foregoing suggests that the requirements for raising green bonds include showing that the proceeds of the bond issue were applied to environmentally friendly projects, that the project is green verified and certified, or the potential to be verified and certified as a green project. Other criteria are a debt programme that will allow the issuer to borrow at least a billion-rand, issuer adhering to the JSE debt listing requirements and auditors must certify that money raised was applied to a green project and otherwise.

4.4 *Green bond constraints*

Regarding the challenges or constraints involved in raising green bonds, all interviewees highlighted associated costs and time factors as seen in the responses below:

> *Respondent 1:* "Data collection is a lot of work, a high minimum debt programme is required and high-interest costs". *Respondent 2:* "High-interest rate and implementation costs". *Respondent 3:* "There is a lot of work that goes into submitting the document that outlines the sustainability of the building, compiling this document makes use of extra administrative costs, interest rates are steep". *Respondent 4:* "debt programme must be at a minimum of 1 billion and high-interest rates".

The foregoing suggests that constraints encountered by corporate firms when raising green bonds include high-interest rates and implementation costs, the minimum amount of funds the company is allowed to borrow is a billion rand on average, this requirement filters most companies out, allowing only big corporate companies access to green bonds, green verification.

Ametepey et al. (2015) found that the barriers to green building raising green bonds are the government's lack of commitment, high interest on green bonds and resistance to cultural change (Banga, 2018). The barriers found in the present study align with those in the literature relating to high-interest rates and implementation costs. Relating to the constraints involved in raising green bonds, lack of knowledge was not cited as a constraint to the adoption of green bonds in contrast to how it is highlighted in the literature. This could suggest that there is progress in the industry's education regarding green bonds.

4.5 *The benefit of green bonds in comparison to other financing instruments for green buildings*

The interviewees were asked to explain how the use of green bonds benefitted the development of green buildings as opposed to other financial instruments. The responses indicate a mixed pattern. While some noted that there were some advantages of green bonds, especially in terms of financing for green building, some others noted that there is no difference between the two financing options.

> *Respondent 1:* "To my knowledge, green bonds offer funds for sustainable development and they serve as a catalyst for green building development and that is how the green buildings benefit from the use of green bonds". *Respondent 4:* "Green bonds only fulfil the purpose of funding green projects. Apart from providing funds for the construction of the green building, there is no other benefit". *Respondent 5:* "There is no benefit really, except for the fact that green bonds promote investment in green building". *Respondent 1:* "The only advantage of using green bonds as opposed to other financial instruments is the fact that green bonds are only allocated to green projects. The environment benefits from green projects and green bonds promote green projects. So, currently, the advantage which green bonds provide benefits the environment and not necessarily the Investor". *Respondent 2:* "Green Bonds have the advantage that there will always be funds for sustainable projects. Green bonds also bring the advantage of giving companies the image that they care about the environment".

The response shows that the provision of funds for green projects which are environmentally friendly is the sole advantage of green bonds. However, some other respondents noted that green bonds have no edge over other financial instruments.

> *Respondent 3:* "Green bonds do not necessarily offer any advantage compared to other financial instruments apart from the fact that they offer funds. Other financial instruments can also offer funds to sustainable projects. So, there isn't any advantage that green bonds bring financially that other financial instruments do not offer". *Respondent 6:* "There is no advantage involved when using green bonds compared to using conventional bonds".

The study found that there is no financial benefit that green bonds provide in comparison to conventional bonds. However, green bonds are a driver for sustainable movement in the construction industry. This is the one benefit that conventional bonds do not offer, and the benefit is that there is less greenhouse gas emission which means that the environment benefits from less harm. Paranque & Revelli (2017) contrasts the issue between green bonds and conventional bonds and indicate the difference to be associated with the environmental impact as anticipated by the investment.

5 CONCLUSIONS

The study aimed to examine the viability of using green bonds as an alternative financial instrument for green building to improve its application in property development in South Africa. Summarily, the green bond market remains underdeveloped with its full potential being inadequately appreciated. Understanding the possible links between financial stability and climate change is one of the factors that encourage an increase in the green bond market. Companies need to spot the gaps they have in terms of their knowledge and get the full advantages of green bond usage. This will help them understand why this is necessary for their company's image and how this practice will benefit the environment. While investors are naturally profit-seekers, investors need to shift from models that focus only on maximising profit, to the models that create environmental, financial and social values, by incorporating environmental-social-governance (ESG) criteria into their investment decision-making.

The study found that the top two constraints that were indicated were high-interest rates and strict criteria for the successful transaction of issuing a green bond. Implementation costs were also listed with high-interest rates and the criteria were broken down to the increased workload for data collection to prove the building is sustainable and administration costs relating to the data collection, and the minimum required debt programme value. Added to the aforementioned constraints, was the availability of green projects to raise the green bonds.

The construction sector perceives the relationship between the use of green bonds and green buildings as a key combination for the benefit of the environment. However, corporate firms find green bonds to be more expensive for use to construct green buildings, compared to conventional bonds. The perception is also that if the interest rate is to be more competitive with that of conventional bonds, the relationship between green bonds and green buildings will be a lucrative investment opportunity that will also benefit the environment.

The study thus recommends that more financial institutions should invest in green bonds so that the green bond market can be a competitive market with numerous investors in the market. The increase in competition could drive the interest rate lower towards competing with conventional bonds. Also, government and municipalities should issue more green bonds to lead the way in setting an example and encourage corporate companies to do the same. If the numbers of borrowers increase, so will the number of investors. This will also mean the borrowing rate will decrease as a result of the characteristics of the perfectly competitive market. In addition, bondholders should offer to make data collection easier for a property owner, so that it is easier to prove that a property is green and also offer to pay 50% of administrative costs for data collection to the bond issuer upon the successful transaction of funds upon the issuing of the green bond. Alternatively, green bonds can also be used for refinancing existing debt of already built green buildings. This will not have any impact on the building itself, only on the debt of the building. The paper has implications for property developers, financiers and built environment professionals, especially as it relates to the viability of raising green bonds in the South African property market. The study provides green bonds as an alternative financial instrument for green building in order to improve its application for property development in South Africa.

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Digital innovation in construction & digital transition

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Drivers for building retrofitting practice: A systematic review

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ABSTRACT: Retrofitting an existing building offers a significant opportunity to improve its performance to solve the problems associated with energy consumption, occupant thermal discomfort, and cost of operation in the building. It is essential to understand what drives the stakeholders, policymakers, and decision-makers in the practices of building retrofitting. Therefore, this study aims to identify the factors motivating stakeholders and house owners to practice retrofitting. This study is based on a systematic review of the literature published in peer-reviewed journals. Scopus and Web of Science were used as scientific databases to find relevant papers. The findings revealed that high energy costs, increased occupant comfort, to maintain or improve the property market/rental value, financial incentives, suitable awareness and attraction to modern technology are some drivers for building retrofitting. This study will help policymakers and advocates better understand the drivers for retrofitting existing buildings and will help to encourage the practice.

Keywords: Drivers, Existing building, Retrofitting, Energy efficiency, Practice

1 INTRODUCTION

Retrofitting existing buildings offers a significant opportunity to reduce global energy use and carbon emissions and improve building performance (Lai et al., 2022; Ma et al., 2012a). For instance, the building sector has been considered a high-profile consumer and emitter of the world's final energy and greenhouse gases (GHG), respectively (Son and Kim 2016; Mejjaouli and Alzahrani 2020). The building energy consumed by such regions as the European Union, United States, Hong Kong, Saudi Arabia and Africa accounts for 40%, 20%, 90%, 77%, and 56%, respectively (DEMS, 2018; Fazli et al., 2021; Z. Liu et al., 2019; Mejjaouli & Alzahrani, 2020; Pallante et al., 2020). Consequently, the building stock in these same regions is responsible for 36%, 40%, 60%, 33%, and 32% CO_2 emissions. Overall, buildings account for 40% and 39% of total global energy use and carbon emissions, respectively (World Green Building Council, 2020).

Energy consumption negatively affects the environment, such as global warming, degradation, and ozone layer depletion (Magdy et al., 2021; Mewomo & Ejidike, 2021). Energy consumption is predicted to rise in existing buildings as urbanization and living standards rise in developing countries like Nigeria, China, Ghana, and South Africa (Liang et al., 2015; Reischl et al., 2019). Therefore, retrofitting the existing building assists in mitigating the negative impact on the built environment (W. "Lisa" Wang et al., 2022). Retrofitting building plays

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a vital role in improving the energy efficiency, water consumption, and occupant thermal comfort of existing buildings for achieving sustainable development in the built environment because new building construction contributes only a tiny percentage of the building stock each year in the built environment (Ashuri & Durmus-Pedini, 2010; Bertone et al., 2018; Golubchikov & Deda, 2012; Zhou et al., 2016). According to Bertone *et al.* (2018), most of these buildings were built before suitable efficiency rules were established, which means they are often inefficient in terms of energy, water, and thermal comfort.

Through incorporating today's best practices in building design, construction, and operation, as well as accelerated state-of-the-art building retrofits (Hong et al., 2020), the global building heating and cooling energy use could be reduced by about 46% by 2050 compared to 2005 values, with the potential for energy and water consumption reductions of up to 40% through building retrofitting in achieving a sustainable built environment (Beal et al., 2012; Bertone et al., 2018; Ürge-Vorsatz et al., 2012; Willis et al., 2011). As a result, retrofitting existing buildings is critical to achieving a sustainable future because the vast majority of the buildings we currently occupy, as well as their respective energy and water use profiles, will be with us for the foreseeable future (Bertone et al., 2018; Sen et al., 2021). Meanwhile, despite all the benefits of building retrofitting globally, the acceptance, practices, and awareness of retrofitting existing buildings are still low in developing countries (G. Liu et al., 2020; Oguntona et al., 2019; Okorafor, 2019). Furthermore, the drivers for practicing building retrofitting are still lacking in the context of literature in developing countries. Hence, this study aims to identify the driving factors motivating stakeholders and house owners to practice retrofitting buildings in developing countries.

2 METHODOLOGY

An in-depth literature review of scientific research is the cornerstone for expanding understanding of a study field (Ejidike & Mewomo, 2023). As a result, it makes it easier to build valuable theories for industrial and academic research (Ghansah et al., 2020). This study primarily reviews pertinent(literature) studies on building retrofitting drivers. Using Elsevier's Scopus and Web of Science (WoS) search engine, a systematic literature search was done to find relevant papers because of its high precision and accuracy in search performance (Halevi et al., 2017; Pranckutė, 2021). The WoS search engine has similarly been utilized to perform a systematic review (Bergman, 2012; A. Caputo & Kargina, 2022). The search keywords used for Web of Science ("drivers" and "existing building" or "retrofitting" AND "energy efficiency" "cost" AND "comfort") and Scopus ("drivers" OR "existing building" AND "retrofitting" OR "energy efficiency" "cost" AND "comfort") and spanning two-decade scientific research 2012 to 2022. The initial results for WoS and Scopus are 50 and 153, respectively (search May 5 2022).

However, in WoS, the retrieved papers were limited to English; and categories such as construction building technology, engineering civil or green sustainable science technology, or environmental studies for the Web of sciences resulted in 57 articles.

Moreover, for Scopus, it was limited to categories such as engineering, environmental science, and energy, resulting in 36 articles. Content analysis was employed to review the retrieved research corpus; Reeve et al. (2015) have similarly utilized this technique. The most-reported drivers of building retrofitting were chosen using a systematic review technique, and several appeals of the drivers by more than two articles (Darko & Chan, 2017; Ghansah et al., 2020) used this process to conduct a systematic literature review.

3 IDENTIFICATION OF DRIVERS ENABLING BUILDING RETROFITTING PRACTICE

A holistic understanding of what could drive or motivate the practice of retrofitting among stakeholders and house owners is essential when practising building retrofitting in developed and developing countries. Therefore, a review of relevant literature to identify the drivers for building retrofitting practices to determine the motivation for retrofitting practices in developing

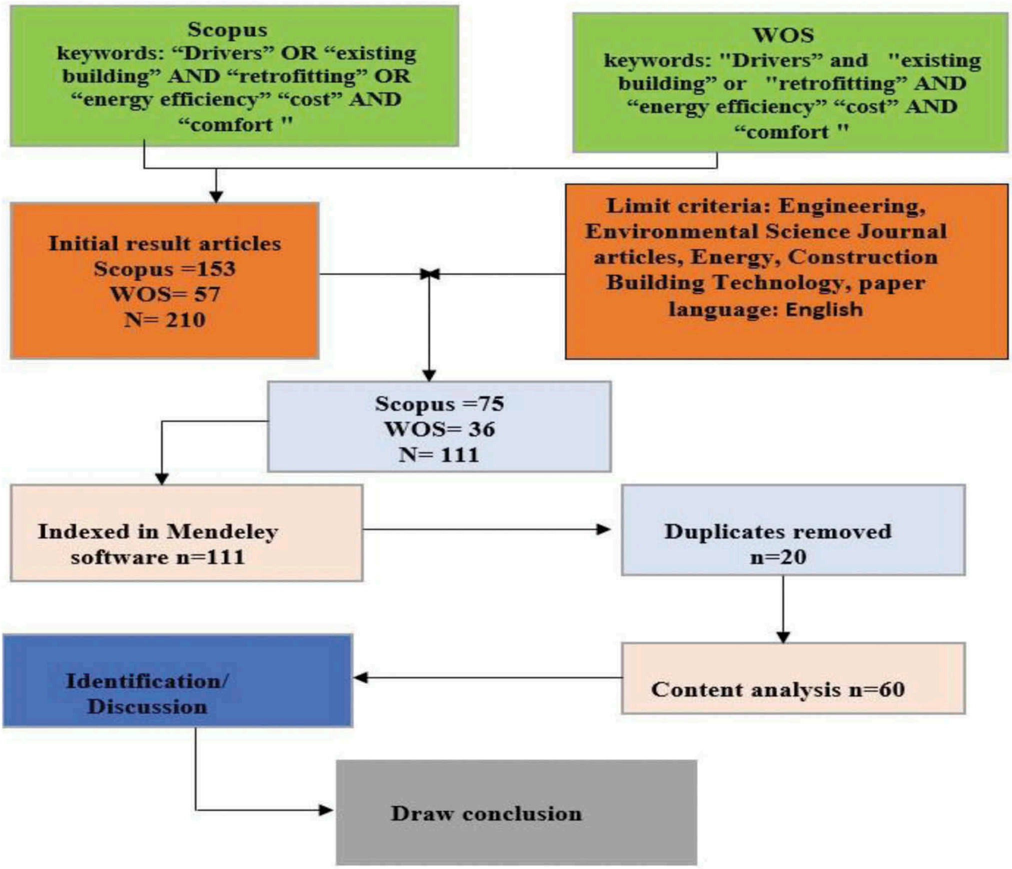

Figure 1. Overview of research approach.

countries to achieve energy efficiency, thermal comfort and operational cost savings in the building. For instance, Hrovatin and Zorić (2018) examined the drivers of home retrofit in Slovenia, identifying financial incentives, educating the public through various information sources, building and space extension, and improved thermal comfort. Furthermore, Caputo and Pasetti (2015) revealed that data availability on a successful project, suitable awareness, and financial concerns are the principal motivation for the municipalities in Italy to practice building retrofitting. Apeaning and Thollander (2013) revealed that cost reductions resulting from lowered energy use, energy tax, highly subsidized industrial energy prices, and threats of rising energy prices are the drivers for practising retrofitting in the Ghanaian industry.

A total of 15 key drivers were found through a study of the 60 articles. However, only drivers identified in at least two studies are included in Table 1. Table 1 shows various drivers of the practice of building retrofitting, each of which has a matching reference.

3.1 *Discussion*

From the literature, other drivers for building retrofitting were identified, which include; improving the house functionality, renovation due in any case, availability of information, attraction to modern technology, management support, environmental and climate protection, improving the house aesthetic, cost reduction from lower energy use, current legal requirements, higher independence from energy or fuel supplier among others. The top-five most frequent drivers that facilitate building retrofitting practice are discussed in this section.

Table 1. Drivers for retrofitting building practices.

S/N	Drivers	Sources	Frequency
1	to maintain or improve the property market/rental value.	(Bond and Perrett, 2012; Haase, Skeie and Woods, 2015; Dixon, 2017; Kaveh *et al.*, 2018; Grossmann, 2019; Heffernan *et al.*, 2021)	6
2	high energy cost.	(Xu and Chan, 2013; Achtnicht and Madlener, 2014; Al-Kodmany, 2014; Pacheco-Torgal *et al.*, 2017; Bottero, D'Alpaos and Dell'Anna, 2018; Hrovatin and Zorić, 2018)	6
3	financial incentives	(Apeaning and Thollander, 2013; Achtnicht and Madlener, 2014; Caputo and Pasetti, 2015; Hrovatin and Zorić, 2018; Fasna and Gunatilake, 2020)	5
4	suitable awareness	(AlSanad, 2015; Cristino et al., 2021; Mohareb et al., 2022; Qarnain et al., 2021; T. Wang et al., 2016)	5
5	improve thermal comfort	(Bond and Perrett, 2012; Aktas and Ozorhon, 2015; Kaveh *et al.*, 2018; Benoit *et al.*, 2021; Hauser and Ryan, 2021)	5
6	improve the house functionality	(Achtnicht and Madlener, 2014; Hatvani-Kovacs *et al.*, 2016; Caputo and Pasetti, 2017; Brown, Sorrell and Kivimaa, 2019)	4
7	renovation is due in any case	(Achtnicht and Madlener, 2014; Caputo and Pasetti, 2017; Brown, Sorrell and Kivimaa, 2019; Rose *et al.*, 2021)	4
8	availability of information	(Ma *et al.*, 2012; Caputo and Pasetti, 2017; Daly, Cooper and Ma, 2018; Hrovatin and Zorić, 2018)	4
9	attraction to modern technology	(Achtnicht & Madlener, 2014; Kivimaa & Martiskainen, 2018; Lucon et al., 2014)	3
10	management support	(Achtnicht and Madlener, 2014; Caputo and Pasetti, 2017; Hrovatin and Zorić, 2018)	3
11	environmental and climate protection	(Güçyeter and Günaydın, 2012; Ma *et al.*, 2012; Mazzarella, 2015)	3
12	improve the house aesthetic	(Caputo and Pasetti, 2017; Kaveh *et al.*, 2018; Martiskainen and Kivimaa, 2019)	3
13	cost reduction from lower energy use	(Haase, Skeie and Woods, 2015; Polzin, Nolden and von Flotow, 2018; Benoit *et al.*, 2021)	3
14	current legal requirements	(Achtnicht and Madlener, 2014; Caputo and Pasetti, 2017)	2
15	higher independence from energy or fuel supplier	(Achtnicht & Madlener, 2014; Apeaning & Thollander, 2013)	2

3.1.1 *To maintain or improve the property market/rental value*

This factor appears the most and is regarded as a key driver for building retrofitting practices, which could be attributed to the desire to increase the monetary value of the building in the market. For instance, Kaveh *et al.* (2018) reiterated that house owners seek long-term value-added and financial gains when investing in building retrofit. Moreover, such retrofit improvements are viewed as an investment in the building for future sale. Also, Heffernan *et al.* (2021) reported that most house owners practice retrofit on the property for financial gain, with resultant improvement in the performance of the building in terms of energy efficiency.

3.1.2 *High energy cost*

Its potential to reduce the energy consumption of existing buildings is one of the primary motivators for building retrofitting. Predicted energy cost reductions through reduced energy use and economic viability are the primary factors of energy-efficient building retrofits. Also, perceptions of high energy prices act as an incentive in most circumstances (Achtnicht and Madlener, 2014; Hrovatin and Zorić, 2018).

3.1.3 *Financial incentives*

Access funds for building retrofitting is essential for building retrofitting practices. Kaveh *et al.* (2018) pointed out that innovative funding models are expected to increase the viability of house owners to practice building retrofitting. Accordingly, they recommended that governments actively support building retrofitting practices such as government loans, government grants, feed tariffs, tax reduction, and low-interest energy

3.1.4 *Suitable awareness*

Demonstrating successful projects is critical for raising awareness of building retrofit. These projects can also be used to demonstrate the financial benefits of such a building. Currently, the number of buildings that demonstrate significant retrofit is still limited. As a result, there is an urgent need to raise public awareness about the importance of achieving building retrofitting.

3.1.5 *Improve thermal comfort*

The desire to practice retrofit needs to consider thermal comfort into account in order to provide a comfortable indoor atmosphere and, as a result, ensure the occupants' health and wellness (Ochedi & Taki, 2022). Benoit et al. (2021) revealed that building retrofit project raises the interior temperature to the standard (usually 20 to 22°C) to increase energy efficiency and comfort levels, thereby motivating the upgrade of lighting, windows, insulation, heating and ventilation systems just a few examples of possible measures.

4 CONCLUSIONS AND IMPLICATIONS

This study focused on examining the drivers enabling the practice of building retrofitting in developing countries. The Elsevier's Scopus and Web of Science search engines were utilized to retrieve relevant academic journals relevant to the research aim using a content analysis approach. Based on the comprehensive literature analysis, some key drivers were identified. However, the common drivers are maintaining or improving the property market/rental value, high energy cost, financial incentives, suitable awareness, and improved thermal comfort. As a result, there are significant drivers to building retrofit practices. The studies have revealed that building retrofitting contributes to developing countries' sustainability and reduce carbon emissions. From the perspective of energy saving and financial point of view, the study assists house owners and professionals in comprehending the drivers towards increasing the practice of building retrofit to achieve fast-growing sustainability in developing countries. Furthermore, it serves as a stir during the decision-making process of building retrofitting practices to achieve sustainability in the construction industry.

Based on the findings and the conclusion of the study, it is recommended that a robust collaboration framework between construction industry professionals and academia be enhanced to increase the awareness of building retrofitting, thereby educating the homeowner on the need to retrofit their buildings.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Factors influencing Building Information (BIM) implementation in developing countries

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ABSTRACT: Infrastructure development is a critical enabler of economic growth in all countries. Hence, the Architecture, Engineering, and Construction (AEC) industry has a very important role to facilitate this economic growth. However, the industry faces a lot of challenges. Therefore, creativity and use of innovative technology is a must to overcome these challenges. Building Information Modelling (BIM) is an emerging technological process that has changed the way the industry functions. This paper is an exposition of factors influencing BIM implementation so that upcoming countries in adopting BIM can learn from other countries. The results have revealed that adoption of BIM has been varying from country to country due to levels of development in each country. Therefore, developing economies should take advantage of the wealth of knowledge which has been generated so far. Finally, provisional sums need to be included in infrastructure projects contract documents for BIM training to facilitate easy adoption.

Keywords: Building Information Modelling (BIM), Developing Economies, infrastructure development, barriers, adoption.

1 INTRODUCTION

Public services and infrastructure are inseparable facets of economic and human development and it is hard to picture one without the other (Africon 2008). According to African Development Bank (AfDB) 2011, infrastructure is a critical enabler of growth in Africa. Across Africa, infrastructure contributed about 99 basis points to per capita economic growth over the period 1990 to 2005, compared with 68 basis points attributable to structural and stabilization policies. However, research has revealed that efficient, ineffective, and even wasted infrastructure investments still occur due to poor planning (AfDB, 2011).

Building Information Modelling (BIM) is a process that has revolutionise the way the Architecture, Engineering and Construction (AEC) firms function since its inception (Arayici, 2011). Brad Hardin, 2015 stated that BIM is one of the developed paradigm shifts and it is a technology-enabled innovative means of virtually designing, constructing, and managing construction projects by simulating a virtual model. According to (Eastman et al., 2011), BIM is a modeling technology and associated set of processes to produce, communicate, and analyze building models.

BIM eases the process of data exchange between members of the project team during design and construction. The technology maximizes productivity, enables clash detection, enhances collaboration and communication, improves visualization, improves project documentation, facilitates design review, improves quality, reduces construction time, conflict/changes, contingencies, and construction cost (Azhar et al., 2012, Adebimpe & Etiene, 2016, Matarneh & Hamed, 2017, Matarneh & Hamed, 2017).

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On the other hand, Azhar et al. 2012, classify BIM application-related challenges in two broad categories namely, technology and process- related challenges. Some of the challenges include legal barriers, lack of support and incentives from construction policymakers to professionals and experts using BIM, unavailability of standards and codes for BIM application, lack of awareness, client demand, small number of specialists in the region, high costs (software, hardware upgrade, training, and time). BIM requires radical changes in workflow, practices, and procedures and, therefore faces resistance to change from design and construction firms.

The adoption of BIM has been hampered by various factors in both developing and developed economies. However, adoption has been relatively fast in developed economies such as the United Kingdom, United States, Hong Kong, China, Australia, Norway, Finland, Denmark, and Malaysia due to strong government support (Wong et al. 2011, Jung and Lee, 2015). The case is contrary in the developing economies such as Nigeria and Ghana where there is often a lack of government support and guidance for technologies such as BIM (Abubakar et al., 2014)

The monitoring or assessment of BIM adoption uses Maturity Model developed by Bew and Richards (2008) using maturity levels between 0 to 3. The objective of categorising BIM into maturity levels from 0 to 3 is to substantiate the types of technical and collaborative working involved at each level and give a comprehensive explanation of the processes, tools, and techniques used (BIWG 2011). For instance, level 0 involves basic CAD features using only drawings, lines, arcs and text. Level 1 includes some basic 3D elements and beginning of BIM. Level 2 involves collaborative BIM and level 3 is the full integration of BIM in project management.

This paper is a literature review, focusing on identifying the major factors and their interrelationships in relation to the BIM adoption in developed and developing economies. The factors herein are categorized into four perspective groups according to areas of influence namely, human resource, industrial, technological and environmental. Each category is analyzed by assigning scores to factors in order to come up with the most critical factor which could be overcome to ensure that BIM adoption is possible.

2 METHODOLOGY AND APPROACH TO SCORING OF FACTORS

Reports from the literature on BIM adoption worldwide are used. Three groups of countries are identified namely, developed economies, economies in transition and developing economies. The classification of the countries is based on the United Nations Development Programme's (UNDP) Country Classification System (Gbadamosi, 2018).

The content analysis of reports is performed to categorise the factors. A thematic classification of individual factors is based on human resource factors, institutional factors, technology factors and environmental factors (see Table 3) (Tamnatzky & Fleischer 1990). A thematic classification of the factors is done so that scoring may assess major factors of influence in adoption of BIM. The actual scoring of a factor is done by counting the total number of reports in which the factor appears per each country classification. A total of twenty-five (25) reports, six from developing economies, four from economies in transition, ten from developed economies, and four are cross cutting studies are considered and content analysis is done for each report. The scores of factors for each type of the country are aggregated numerically to determine the most critical factor. The factors in the individual thematic classification in developed and developing economies are summarized in Table 2 and Table 3 respectively.

3 RESULTS

3.1 *Developed economies*

Content analysis of reports from six developed economies namely, United Kingdom, Hong Kong, China, Australia, Kuwait, and Finland was performed, with United Kingdom showing dominance in BIM-related reports (see Table 1). The all countries except Kuwait have achieved level 3 of maturity of BIM adoption. The higher level of adoption is attributed to governments or authority's deliberate policies to promote BIM adoption. For instance, UK Government has set a target of 2016 for BIM adoption (Eadie R. et. al., 2013). Hong Kong has implemented the BIM system in more than 19 public housing projects in the design and implementation stages since 2006 (Shaban M & Elhendawi A. 2018).

The scoring of the various thematic classification in developed economies are summarized in Figure 1.

Table 1. Maturity levels of developed economies.

Country	Level Of BIM Maturity	References
United Kingdom	Level 3	Eadie et al (2014) Odeyinka & Mc Keown (2014). Eadie and Johnson (2013) Gledson, Herny & Bleanch (2012). Machado, Underwood & Fleming (2014).
Australia	Level 3	Monazam, Hamidimonazam, Hosseini & Zaeri (2016); and Newton & Chileshe (2012).
China	Level 3	Ma, Shen & Tian (2021).
Kuwait	Level 2	Gerges, Ahiakwo, Jaeger & Asaad (2016).
Hong Kong	Level 3	Chan, Olawumi & Ho (2019).
Finland	Level 3	Halttula, Haapasalo & Herva (2016).

Figure 1 shows that institutional thematic factors are critical in developed economies due to high cost of buying and updating software. Human Resource Factors are second highest attributable to lack of training for architects, quantity surveyors and engineers due to costly training requirements in terms of time and money scored the highest. Environmental factors entail legal risk/copy right issues (Saka & Chan, 2019), (Elhendawi et. al 2019) and (Fadason et al., 2018).

3.2 *Economies in transition*

In the economies in transition category, all countries are in level 2 of BIM adoption (see Table 4). This is a 'Collaborative BIM' stage which includes the required information, supply chain management, and requires teams to be working together with 3D. In South Africa, the Construction Industry Development Board (CIDB) through the Construction Industry Development Board Act No. 38 of 2000, has been created by the South African Government "to implement an integrated strategy for the reconstruction, growth and development of the construction industry and to provide for matters connected therewith" (Construction Industry Development Board, Act No. 38, 2000). This Board is also responsible to oversee the adoption of technologies such as BIM (Odubiyi et. al., 2019).

Considering the factors influencing BIM adoption, economies in transition have the following which are in order of importance (i) lack of training for architects, for experts due to costly training requirements in terms of time and money, (ii) lack of experts (iii) lack of Government regulations to support implementation of BIM, (iv) high cost of buying and updating software, and (v) lack of investment on BIM.

3.3 *Developing economies*

In the developing economies category, two countries are in Level 0 and the other two are in Level 1 as shown in Table 5. Level 0 as shown in Table 1, is basically use of CAD whilst level 1 is the beginning phase of BIM adoption. Saka A. & Chan D. (2019) stated that there is a lot of awareness of BIM in Africa, however uptake is very slow. This is a typical example of most developing economies.

Table 2. Thematic classification of factors in developed economies.

Thematic Classification of individual factors				
Human resource	Institutional	Technological	Environmental	References
Poor collaboration of BIM information among stakeholders	Lack of Government regulations to support implementation of BIM	Uncertainty over interoperability of BIM software with other software (compatibility)	Lack of case studies in developing countries that have implemented BIM and realised positive investment returns	Eadie, Browne, Odeyinka & Mc Keown (2013)
Lack of training for architects, quantity surveyors and engineers due to costly training requirements in terms of time and money	High cost of buying and updating software	Lack of BIM tools for project management	Need for a new, dynamic and diverse contractual/procurement environment	Monazam, Hamidimonazam, Hosseini & Zaeri (2016)
Lack of awareness of BIM by stakeholders	Resistance to adopt new technology due to change in workflow system in companies	Lack of technical support/data management	Lack of ICT Infrastructure	Hannan, A., Kamran, M., & Tahir, T. Bin (2019)
Lack of knowledge of BIM application by stakeholders	Inadequate finance in small firms to start new workflow system for BIM	Lack of Investment on BIM	Cultural differences	Eadie & Johnson (2014)
Lack of awareness of benefits of BIM by stakeholders	Difficulty in involving Contractors in project early stages	Lack of clear BIM benefits evaluation	Normative Support	Gledson, Herny & Bleanch (2012)
Lack of training at the University and Colleges on BIM application	Lack of demand and interest from clients on the application of BIM in the design and construction of projects	Impaired productivity due to initial implementation	Lack of Support from other industry partners	Gerges, Ahiakwo, Jaeger & Asaad (2016)
Resistance to change from CAD from BIM System	Lack of BIM standards	Inadequate BIM application research and development	Lack of demand	
Lack of Interest	Lack of management support	Misunderstanding of BIM technology	Legal risk/copy right issues	Chan, Olawumi & Ho (2019)
Lack of user satisfaction	Business agility	BIM is complex in use	No risk insurance	Ma, Shen and Tian (2021)
Lack of motivation or incentives	Lack of industry readiness	Uncertainty over interoperability of BIM software with other software (compatibility)		Machado, Underwood & Fleming (2014)
Lack of experts	Structuring of fees	Lack of BIM tools for project management		Eadie, Odeyinka, Browne (2013)
High cost of staff training	BIM impact on procurement	Lack of technical support/data management		
	Model Hosting	Lack of Investment on BIM		Halttula, Haapasalo & Herva (2016) Newton & Chileshe (2012)

Table 3. Thematic classification of factors in developing economies.

Thematic Classification of individual factors				
Human resource	Institutional	Technological	Environmental	References
Poor collaboration of BIM information among stakeholders	Lack of Government regulations to support implementation of BIM	Uncertainty over interoperability of BIM software with other software (compatibility)	Lack of case studies in developing countries that have implemented BIM and realized positive investment returns	Saka & Chan (2019)Nasika & Cloete (2019)
Lack of training for architects, quantity surveyors and engineers due to costly training requirements in terms of time and money	High cost of buying and updating software	Lack of BIM tools for project management	Need for a new, dynamic and diverse contractual/procurement environment	Saka, Chan & Siu (2020) Shaban & Elhendawi (2018)
Lack of awareness of BIM by stakeholders	Resistance to adopt new technology due to change in workflow system in companies	Lack of technical support/data management	Lack of ICT Infrastructure	Rogers, Chong, & Preece (2015)
Lack of knowledge of BIM application by stakeholders	Inadequate finance in small firms to start new workflow system for BIM	Lack of Investment on BIM	Cultural differences	Ma, Shen & Tian (2021) Elhendawi, Omar, Elbeltagi & Smith (2019)
Lack of awareness of benefits of BIM by stakeholders	Difficulty in involving Contractors in project early stages	Lack of clear BIM benefits evaluation	Normative Support	Odubiyi, Aigbavboa, Thwala & Netshidane (2019)
Lack of training at the University and Colleges on BIM application	Lack of demand and interest from clients on the application of BIM in the design and construction of projects	Impaired productivity due to initial implementation	Lack of Support from other industry partners	Al-Btouch & Haron (2017)
Resistance to change from CAD from BIM System	Lack of BIM standards	Inadequate BIM appication research and development	Lack of demand	Fadason. Danladi & Akut (2018).
Lack of Interest	Lack of management support	Misunderstanding of BIM technology	Legal risk/copy right issues	Elhendawi, Smith & Elbeltagi (2019)
Lack of user satisfaction	Business agility	BIM is complex in use	No risk insurance	Hammaadama, Kouider & Salman (2018)
Lack of motivation or incentives	Lack of industry readiness			
Lack of experts	Structuring of fees			
High cost of staff training	BIM impact on procurement			
	Model Hosting			

Figure 2 shows summarized scores of the factors per thematic classification.

Figure 2 indicate that human resource factors are critical in developing economies and this is attributed to lack of training for architects, quantity surveyors and engineers due to costly training requirements in terms of time and money. Institutional Factors show the second highest due to high cost of buying and updating software. Uncertainty over interoperability of

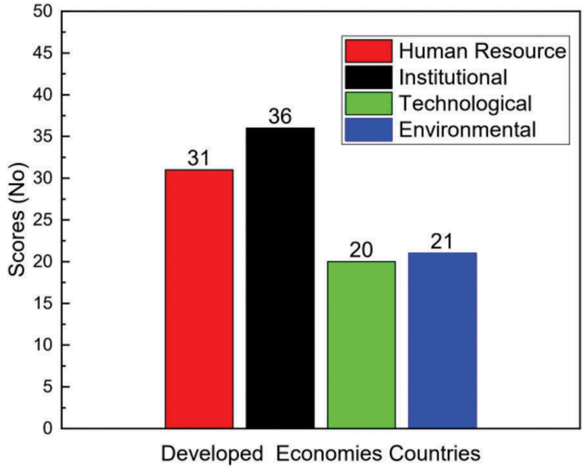

Figure 1. Factors affecting BIM adoption in the developed economies.

Table 4. Maturity levels of economies in transition.

Country	Level Of BIM Maturity	References
Malaysia	Level 2	Rogers, Chong, & Preece (2015).
South Africa	Level 2	Odubiyi, Aigbavboa, Thwala & Netshidane (2019).
Nigeria	Level 2	Ruya, Chitumu, & Kaduma (2019); Hanna-Adama, Kouider & Salman (2019)

Table 5. Maturity levels of developing countries.

Country	Level of BIM Maturity	References
Kenya	Level 0	Mutonyi & Cloete (2018)
Syria	Level 0	Shaban & Elhendawi (2018).
Jordan	Level 1	Al-Btouch & Haron (2017).
Saudi Arabia	Level 1	Elhendawi, Omar, Elbeltagi & Smith (2019); Elhendawi, Smith & Elbeltagi (2019).

BIM software with other software (compatibility) is the major factor contributing to an appreciable score of Technological factors. The environmental factors entail legal risk/copy right issues.

4 DISCUSSIONS

Proper planning of BIM implementation is a prerequisite of ease and proper uptake by stakeholders in both developed and developing economies. As it has been observed in levels of maturity, most developed economies are ahead in adoption of BIM than in developing economies. On the other hand most of the developing economies have a very low uptake of BIM. Economies in transition are just slightly better than most of the developing economies. As stated by Saka & Chan (2019), there are more publications from North Africa, West Africa, and Southern Africa, than East and Central Africa. This mainly depicts countries whose economies are in transition. Hence adoption of BIM mainly depends on development level of the countries.

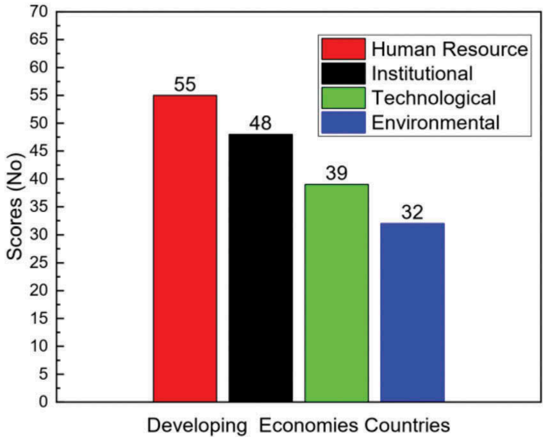

Figure 2. Factors influencing BIM adoption in developing economies.

This study has provided factors which influence BIM adoption in both developed and developing economies. Adoption of BIM tool in developed economies is mostly affected by institutional factors whilst in developing economies it is mainly affected by human resource factors. However, it has been observed that both developed and developing economies have similar factors which have impact on BIM adoption. The top four factors are as follows: high cost of buying and updating software; lack of training for architects, quantity surveyors and engineers due to costly training requirements in terms of time and money; uncertainty over interoperability of BIM software with other software (compatibility); and legal risk/copy right issues. As stated by Teng et al., (2022), most stakeholders are still resisting change and are unwilling to invest in BIM technology for economic reasons. Hence for developing economies to ably adopt BIM, it would be important to critically consider these raised factors in its strategies of BIM adoption.

5 CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the study has revealed that there are a number of factors which can hinder the adoption of BIM such as high cost of buying and updating software; lack of training for professionals due to costly training requirements in terms of time and money; uncertainty over interoperability of BIM software with other software (compatibility); and legal risk/copy right issues. However, upcoming countries should take advantage of the wealth of knowledge which has been generated over the last decades by developed economies to easily adopt BIM.

It is recommended that provisional sum need be included in contract documents of infrastructure works and consultancies to be used for training of experts for BIM tool so that adoption could be easily facilitated. Secondly, it would be important for the Governments to come up with the regulatory framework, policies and strategies for BIM adoption. And mandatory use of BIM in projects could also be considered to ensure full adoption of BIM.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

An analysis of the utilization of omnidirectional cameras to monitor the unsafe behaviour of construction workers

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ABSTRACT: The construction industry is focusing on using digital technologies to monitor workers' unsafe behaviour as they perform their duties. This study aims to assess how omnidirectional cameras can be used to monitor unsafe behaviour among construction workers. This study used a systematic literature review approach for data collection to achieve this objective. The results show that an automated proximity visualization system can use closed-circuit television (CCTV) video from a construction site to alert workers when hazardous objects are getting close. Furthermore, omnidirectional cameras are also utilized to observe complex situations on real construction sites, and these cameras can be enhanced with a variety of layers of safety-related data. As a result, the application of omnidirectional cameras has had a lot of promise for monitoring unsafe worker behaviour if proper recommendations are implemented. Future research should focus on monitoring construction workers' unsafe behaviour on actual construction sites using omnidirectional cameras.

Keywords: Accidents, Construction Industry, Omnidirectional Camera, Unsafe Behaviour

1 INTRODUCTION

The construction industry is an extremely substantial risk, and the unsafe behaviour of workers is thought to be a critical factor in that risk level. Workers' unsafe behaviour is the main contributor to accidents in the construction industry (Yang, et al., 2021). Several reasons why accidents happen also highlight the unsafe behaviour of workers as a major factor in safety incidents. For instance, 904 workers were killed in China in 2019 while working on housing and municipal engineering projects (Kong et al., 2021). In addition, Guo et al., (2019) stated that 96% of injuries experienced in the construction industry were related to the unsafe behaviour of workers. Compared to other industries, the risk of potential injuries and even death at work is higher for construction workers (Li et al., 2017).

Despite the significant research that has been done to identify and address the unsafe behaviour of workers in the construction industry, accidents still pose a fundamental problem. Unsafe behaviour occurs when personnel operate in a way that standards, processes, safety norms, and instructions are not followed (Sugumaran, 2017). Unsafe behaviour encompasses a wide range of acts, such as sleeping on ledges, climbing without permission, and forgoing the required personal protective equipment (PPE) (Ulang, 2014: 1). In addition, the concept of unsafe behaviour emphasizes the propensity of an individual to disregard safety regulations, practices, directions, and criteria for operating the prescribed (Sugumaran, 2017).

As a result, the construction industry is focusing on using digital technologies to monitor workers' unsafe behaviour in real-time (Kong et al., 2021). Omnidirectional cameras are

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widely used in motion capture technology to record videos of workers' movements, which can then be compared with videos showing unsafe behaviour (Yu et al., 2017). For instance, the deployment of omnidirectional cameras can continually locate workers based on their activities, follow their movements throughout the workplace, forecast the types of actions they will take, and alert management if it observes unsafe behaviour that could lead to accidents. It is further reported by Meegoda et al., (2019) that digital video is an advanced visual inspection method that has been utilized to improve inspections of areas which are hard to reach especially in the construction industry. As a result, the applications of cameras on construction sites would record workers without any attached markers or devices, and the workers' motions would be automatically analyzed using the recorded video (Han & Lee, 2013).

Therefore, this study is aimed at evaluating the use of omnidirectional cameras to monitor the unsafe behaviour of construction workers. The next section provides a summary of the research method used in this study. The study's results and discussion are presented. Conclusions and recommendations are then presented.

2 RESEARCH METHODS

This study aims to assess how omnidirectional cameras can be used to monitor unsafe behaviour among construction workers. To achieve this objective, this study used a systematic literature review approach. A systematic review is defined as a disciplined and repeatable process for locating, analyzing, and selecting all material pertinent to a specific quality level (Purssell & McCrae, 2020). The benefit of this approach is that it makes technical assessments more rational and consistent, which gives readers objectivity and transparency throughout the review process. According to Briner & Denyer (2012), a systematic literature review is preferred because it meets the following criteria, the study must be conducted using a systematic system or process, it must present a clear and explicit methodology, and it must be repeatable and updatable, and it must summarize and synthesize the data supporting the review topic.

The "Scopus," "Google Scholar," and "Web of Science" databases were used to search for relevant data available because the integration of omnidirectional cameras for monitoring construction workers' unsafe behaviour is documented and has been mentioned in these databases. As shown in the studies by Wurtz et al. (2019: Havârneanu et al., Paran, 2015; Pereira et al., 2018), the identified databases were chosen since it was discovered that they had a wider range, accuracy, and ease of accessing publications. The publications in the selected databases were searched using keywords like "omnidirectional camera in construction" and "monitoring construction workers' unsafe behaviour." The titles and abstracts of the selected publications were reviewed, and if they were found to be relevant to the study's objectives, the full papers were screened. Therefore, publications that were published between 2012 and 2022, or within the last 10 years, were analyzed because this study examined the use of digital technology to monitor workers' unsafe behaviour. As a result, 33 papers were cited in this study as illustrated in Figure 1. During the literature screening procedure, publications that did not address the study's goal were excluded. The flowchart for the systematic literature review in this study is shown in Figure 1.

3 APPLICATION OF AN OMNIDIRECTIONAL CAMERAS

Omnidirectional cameras are a reality-capturing technology that produces an uninterrupted image of the entire area surrounding an observer, creating a feeling of presence, of being there (Pereira & Gheisari, 2019). According to Jayasuriya et al., (2020), an omnidirectional camera captures views from all directions, making it ideal for recording both indoor and outdoor activities. In addition, omnidirectional cameras, also known as 360-degree cameras, are more affordable, lighter solutions that can even be put on drones (Mi & Yang, 2019). As a result, drones can capture high-quality video in hard-to-reach areas by using omnidirectional cameras.

Omnidirectional cameras have been used in several fields as a technique for the immersive depiction of physical surroundings. For instance, Meegoda et al., (2019) evaluated the use of a 360-

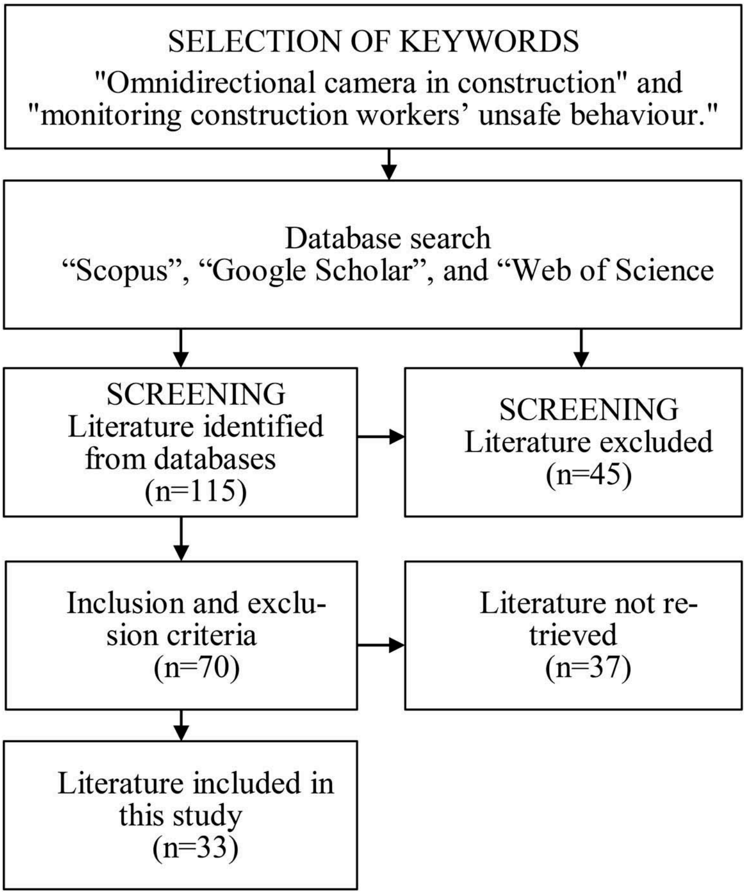

Figure 1. Systematic literature review flowchart.

degree camera made up of two separate 180-degree fisheye lenses to take a clear visual record of the interior of a culvert on a construction site. The authors discovered that the 360-degree perspective images were much more accurate than those from a typical CCTV camera, catching 99.3% of the defects in the culvert's interior. Mi & Yang (2019) further used 360-degree cameras as a learning tool and analyzed the effects of immersiveness of three devices: a smartphone, a Google Cardboard, and an Oculus Rift during online learning. In addition, a 360-degree camera was installed in UP-drive vehicles to enhance autonomous parking and navigation in crowded urban areas (Petrovai & Nedevschi, 2022).

The most prevalent application of 360-degree cameras is the creation of virtual tours (Pereira & Gheisari, 2019). In this case, the authors illustrated that the use of virtual tours to preserve historical sites and their histories provides access to online museums and represents artwork and architectural designs. For a more realistic experience, users can view 360-degree images and videos using a virtual reality headset alongside more conventional viewing tools like smartphones and personal computers (Jokela et al., 2019). As a result, increased applications for the new devices in 360-degree cameras are emerging, including robotics, vehicle traffic control, and intelligent surveillance systems (Delforouzi et al., 2016).

4 ADOPTION OF 360-DEGREE CAMERAS IN THE CONSTRUCTION INDUSTRY

According to Pereira & Gheisari (2019), 360-degree cameras have been utilized by researchers in the construction industry to imitate remote, challenging, or hazardous construction sites in the real world. In addition, many construction companies set up closed-circuit television (CCTV) on construction sites for video surveillance (Kim & Chi 2017). For instance, 360-degree cameras have been used to visualize hazard identification in the construction industry (Eiris et al., 2020-a). In this study, the platform was assessed for fall hazard identification, and it was discovered that participants accurately recognized, on average, 52% of the hazards in such a setting. Additionally, a 360-degree camera with high resolution is required while checking walls on construction sites to find cracks in the walls (Trana et al., 2020). It has been shown that the construction industry is embracing 360-degree cameras for three purposes: interactive learning, reality background for augmented information, and visualizing safe and unsafe conditions (Pereira & Gheisari, 2019).

In terms of adopting interactive learning in the construction industry, Gheisari et al. (2015) used a 360-degree interactive panorama as a practical and location-independent solution to display a building's structure in a particular location and show students free-body diagrams of the building's structural components. This study found that students may experience being in front of a building structure, engaging with its many structural components, and examining related free body diagrams without being on a construction site. Moreover, a 360-degree panorama-based safety immersive storytelling technique was also used by Eiris et al., (2020-b) to enhance trainees' risk perception and hazard awareness in the context of electrical trade fall hazards to construction management students.

Regarding the use of reality backgrounds for augmented information in the construction industry, Pereira & Gheisari (2019) pointed out that augmentations used in 360-degree panorama provided a simple method for locating and visualizing various building components and documenting potential issues in the construction processes for later remote communication between stakeholders. Additionally, Eiris et al. (2018) observed that augmented 360-degree panoramas of reality provide a ground-breaking alternative that generates inexpensive, straightforward-to-capture, realistic representations of the actual construction sites where trainees may practice spotting risks.

In terms of including both safe and unsafe conditions in the construction industry. 360-degree cameras were employed by Pereira et al. (2018) to see complicated circumstances on actual building sites, and these cameras can be improved with several layers of safety-related data. This study found that despite offering viewers a sense of immersion, panoramic augmented reality provides extremely comprehensive and accurate depictions of actual construction sites. Pereira & Gheisari (2019) also noted the usage of 360-degree cameras as a visualization tool for hazard awareness and detection in the construction industry.

5 360-DEGREE CAMERAS TO MONITOR CONSTRUCTION WORKERS' UNSAFE BEHAVIOUR

Considering the nature of the construction industry, workers usually do their duties in teams. Interpersonal interactions among construction workers play a considerable influence in establishing or modifying safety behaviour (Shia et al., 2019). Therefore, one of the major factors contributing to accidents on construction sites is the unsafe behaviour of workers (Yang, et al., 2021). The usage of computer vision-assisted technology is growing in popularity as a means of overcoming these restrictions and limitations. This system offers a useful technique for automatically detecting the unsafe behaviour of workers on construction sites (Liu et al., 2021). Computer vision is an interdisciplinary field that focuses on how computers may offer enriched data to support and acquire an understanding through digital images and videos (Guo et al., 2019).

As a result, image and video processing recorded through 360-degree cameras thus serves as a different option from behaviour and safety monitoring (Shin & Kim, 2022). This is because joint mobility can be used to track changes in working behaviour while changes in the size of the identified item over a series of photos can be used to estimate changes in worker behaviour. However, the conventional method of processing image data for visualization uses straightforward image data aggregation models, in which video data is collected by cameras and transferred to the cloud where it is cleaned, combined, and added to image data. Finally, the cloud will make use of the combined image data to create uniform models for addressing the unsafe behaviour of construction workers (Li, et al., 2021).

To provide a precise visual surveillance system for identifying unsafe behaviour among construction workers, 360-degree cameras are primarily used. For instance, Shin & Kim (2022) developed a ground-breaking automated proximity visualization system to monitor the safety of construction workers. As a result, the developed system can use CCTV from a construction site to warn workers when potentially dangerous things are approaching. Furthermore, the authors discovered that a visualization strategy for workers' safety consists of locating a piece of equipment precisely in space, placing it there, and using proximity sensing to consider the perception of the workers as determined by their position. In another study, Han & Lee (2013) developed a framework for vision-based motion capture and identification to identify the crucially unsafe behaviour of construction workers on a construction site. The results indicate that a vision-based motion capture and recognition framework could support continuous and automatic monitoring of workers, feedback, and behaviour management to ensure the safe performance of the activity.

A real-time smart video surveillance monitoring system was provided by Luo et al. (2020) to identify individuals approaching hazardous locations on a construction site. The result demonstrates that a real-time smart video surveillance monitoring system was capable of effectively identifying items from video surveillance in hazardous areas. Additionally, Kolar et al. (2018) developed a safety guardrail detection model based on a convolutional neural network (CNN) to enhance the safety inspection of conditions and behaviour that significantly rely on human efforts. According to this work, a large training dataset may be produced using the artificial images produced by augmenting technology, and the CNN-based image detection algorithm is a potential method for monitoring the safety of construction sites.

6 DISCUSSIONS

This study's objective was to assess how omnidirectional cameras can be used to monitor unsafe behaviour among construction workers. This is because the construction industry has an extremely prominent level of risk, which is thought to be influenced by the unsafe behaviour of construction workers. According to Yang, et al., (2021), construction workers' unsafe behaviour is the primary contributor to accidents in the industry. Additionally, it has been reported that working relationships have a significant impact on developing or changing safety behaviour on construction sites (Shia et al., 2019). According to Kong et al., (2021), the construction industry is attempting to monitor workers' unsafe behaviour using digital technologies. For instance, omnidirectional cameras, usually referred to as 360-degree cameras, are used in the construction industry to simulate remote, difficult, or hazardous construction sites (Pereira & Gheisari, 2019).

Omnidirectional cameras are used in motion capture technologies that have attracted the interest of the construction industry (Yu et al., 2017). These technologies are primarily employed in the identification and biomechanical analysis of unsafe behaviours. The four-step procedure used by these technologies is shown in Table 1. These four steps process led to the creation of a simplified image-based unsafe behaviour detection approach that can quickly identify workers' unsafe behaviours by streamlining behaviour data and developing an identification algorithm.

Table 1. Motion capture technologies in four steps.

Procedure	Description
Step 1	Collecting sample data (joint sensor data, RGB-D image and stereo camera image)
Step 2	Reducing dimension,
Step 3	Extracting the features of motions from the sample data
Step 4	Identifying test motions by comparing their features with the features in Step 3

According to Luo et al., (2020), a real-time smart video surveillance monitoring system was also developed to detect individuals approaching hazardous locations on a construction site. In this study, it was observed that a warning is sent out when a worker enters a hazardous location, minimizing the possibility that the individual may have performed unsafe acts. The fact that this device captures the action in real time enables site management to identify incidents of unsafe behaviour. As a result, it can be argued that on-site surveillance camera systems have been utilized to remotely monitor safety in an attempt to decrease occupational accidents in the construction industry.

7 CONCLUSION

Numerous studies have revealed that interactions between workers in the construction industry have a significant impact on how safe behaviour is developed or changed. The unsafe behaviour of construction workers is a major contributing factor leading to accidents in the industry. This study assessed how omnidirectional cameras can be used to monitor unsafe behaviour among construction workers using a systematic literature review. To compare images of worker behaviour to images of unsafe behaviour, it is revealed that cameras are widely used in motion capture technologies. An automated proximity visualization system, for instance, can use CCTV video from a construction site to alert workers when hazardous objects are getting close. 360-degree cameras are also utilized to observe complex situations on real construction sites, and these cameras can be enhanced with a variety of layers of safety-related data. This study found that, despite providing viewers with a sense of immersion, panoramic augmented reality provides incredibly detailed and accurate depictions of actual construction sites. A related study developed a framework for vision-based motion capture and recognition to provide continuous and automatic worker monitoring, feedback, and behaviour management to guarantee the activity's safe performance. It can therefore be recommended that 360-degree cameras would help to monitor construction workers' unsafe behaviour to avoid accidents since this study relied on data collected from numerous researchers through a systematic literature review. Furthermore, it is recommended that future studies concentrate on incorporating 360 degrees to monitor the unsafe behaviour of construction workers using real-world construction sites.

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Environmental and waste management/facilities & real-estate management

Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Disaster management adaptation for peri-urban areas: A case of Zambia

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ABSTRACT: Low-income unplanned settlements, such as peri-urban areas, with poor drainage infrastructures are vulnerable to the effects of flooding and are exposed to risks of water-related disease outbreaks. This research endeavours to assess the problems in the actions and strategies in disaster management governance to coherently address flooding disasters and public health aspects, using a Straussian Grounded Theory approach. Four key phenomena are established that needs enhancement to improve disaster management with adaptive robustness for peri-urban areas. These include: cultural behaviour of public institutions towards flood disasters; non-peri-urban area-specific viability of flood disaster management; effect of interdependencies among institutions in flood disaster management governance; and the necessity of community participation as part of flood disaster management. These observable phenomena help explain consequential paradigms that provide a premise for decision-makers, policy makers, and planning authorities to structure adaptive implementation strategies to address peri-urban concerns with regards to flooding disasters and public-health.

1 INTRODUCTION

Flooding is a pressing climate change concern in most recent years across the world (Munzhedzi et al., 2016; Schaer & Hanonou, 2017). Flooding as a disaster is when a high flow of water overtops either the natural or artificial banks of a river and therefore induces disasters. Disasters occur when human settlements have an overflow of water beyond the normal confines and humans are unable to cope with the calamity (Disaster Management Operations Manual 2015; Sena & Woldemichael 2010; Kouadio et al. 2012). Climate change and flood disasters have received a lot of attention in places like Africa as the frequency and intensity of floods have grown (Mudenda et al., 2022b). Depending on the nature and severity of the consequences of rainfall and climate change, flood disasters can further significantly affect people's livelihoods due to water-related illness and pandemic impacts (Munzhedzi et al., 2016; Schaer & Hanonou, 2017). Disaster management must focus on prevention/mitigation, preparedness and response in order to reduce or eliminate potential losses from hazards, offer prompt and appropriate help to survivors of disasters and ensure a speedy and successful recovery (Carter, 2008; Gupta et al., 2016; Islam et al., 2016).

According to Kouadio et al. (2012), Sena & Woldemichael (2010) and Siriwardana et al. (2018), the efficiency of institutional prevention or mitigation, preparedness and response, disaster management phases affect resilience in the face of a flooding disaster. The literature makes it clear that municipalities, companies that supply water and sewage services, non-governmental organizations, hospitals, and the general public are all involved in flood disaster management

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governance. According to Gupta et al. (2016), Islam et al. (2016) and Mudenda et al. (2022a), disaster management governance is the process through which different stakeholders coordinate the execution of disaster management at the national, regional and local levels.

In Zambia, particularly during the rainy season, water, sanitation and hygiene are a public health problem (Nyambe et al., 2020; Nyambe & Yamauchi, 2021). Low-income unplanned communities, like peri-urban areas, have inadequate drainage systems that make them susceptible to floods. A peri urban area is characterized by a high incidence of poverty, a high population density and initially an unplanned informal or formal settlement within the jurisdiction of a Local Authority (DTF, 2005; Mudenda et al., 2022b). As seen by the rise in water-related illness epidemics during the rainy season, this is a major public issue (Munzhedzi et al., 2016; Schaer & Hanonou, 2017; Mudenda et al., 2022a). Long-lasting rainfall in Lusaka has led to flooding, which raises the risk of cholera outbreaks and transmission (Mwaba et al., 2020). The majority of these infectious illness cases occur in peri-urban and rural settings, where a lack of adequate sanitation contributes to an elevated risk of disease breakout (Mwaba et al., 2020). Poor sanitation, a lack of access to clean water and poor hygiene are issues that are exacerbated in peri-urban regions and contribute to these epidemics (Moon & Keeffe, 2021). Due to the public health concern effects from flooding disasters, it is inherent that flooding disasters and public health aspects (water, sanitation and hygiene) need to be coherently addressed under flooding disaster management governance. In a study by Mudenda et al. (2022b), findings indicate that there is need for disaster management implementation mechanisms with adaptive approaches addressing peri-urban concerns in reducing public health-flooding disaster risks. Depending on the circumstance, there are various definitions for adaptable techniques. The act or process of altering to better suit a circumstance is referred to as adaptation in this context (Stratton, 2014; Terziev & Stoyanov, 2018; Munzhedzi et al., 2016). Therefore, with the goal of coherently addressing flooding disasters and public health aspects in peri-urban areas, the study's results seek to identify the emerging issues and demands in improvements of such mechanisms in peri-urban area disaster management governance. It is with this background that the authors make use of the Straussian Grounded Theory described in the following section.

2 METHODOLOGY

In this research, the authors endeavour to assess the problems in the actions and strategies in flooding disaster management governance to coherently address flooding disasters and public health aspects (water, sanitation and hygiene) in peri-urban areas. The authors take the case of Kanyama compound in Zambia. Due to its geographic location, underlying geological formation, and climatic conditions, Kanyama is a peri-urban area that is among the most disaster-prone areas and frequently experiences natural disasters, including floods, which typically result in lives and property being lost every year (Phiri, 2014).

This paper seeks to avoid formulating pre-existing theories about the new problems in the area under examination. Instead, this study uses a Grounded Theory methodology and an inductive approach to characterize these emerging issues and observable phenomena. A collection of systematic methods for extracting information from data in order to build a theory that is supported by empirical evidence are included in the grounded theory qualitative approach (Vollstedt & Rezat, 2019). Following a Straussian Grounded Theory approach, the authors establish emergent issues detrimental to this scope of disaster management for peri-urban areas (Figure 1).

Thanks to the use of pre-existing theoretical knowledge based on a sound methodological and epistemological foundation, the researchers were able to distinguish between notions that force data and concepts that enable the emergence of new categories by employing the Straussian Grounded Theory. Before starting the study using this methodology, the writers relied on theoretical knowledge to have some acquaintance with the subject of interest. Preconceived notions cannot be avoided while using this strategy. This approach is different from Glaserian Grounded Theory, which recommends that the researcher join the study environment without any predetermined research questions or challenges in mind, but rather with a broad theoretical underpinning that is not immediately disclosed.

Following this technique, the researcher collected qualitative data using a structured analytic method of inquiry. Semi-structured interviews were used as the mode of inquiry for data collection. Participants were chosen from a list of government organizations. The study of narrative-style data is a key emphasis of the grounded theory approach (Vollstedt & Rezat, 2019).

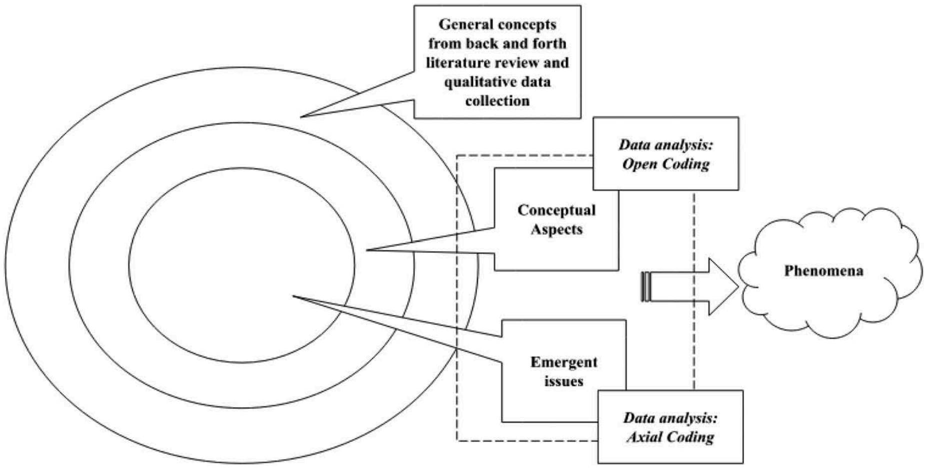

Figure 1. Methodology, taking a straussian grounded theory approach.
(Source: author, adapted from Vollstedt & Rezat (2019))

As a result, these institutions and their respondents were sampled using a purposive and deliberate mixed sampling technique, which is focused on understanding contexts rather than the volume of replies. Utilizing purposive sampling, respondents were originally chosen from specified relevant representative public institutions based on their presumed significance to the topic matter of this study, as suggested by the literature and an initial interpersonal encounter. These respondents determined the snowball sampling used during data collection and helped discover other significant research participants to include in the study. In the end, respondents for the research came from government organizations and included participants from: the Disaster Management and Mitigation Unit (DMMU), the Ministry of Health (MoH), where Kanyama General Hospital was chosen, Zambia National Public Health Institution (ZNPHI), Lusaka Water Supply and Sanitation Company (LWSC) and the Ministry of Local Government and Rural Development (MLGRD). Institutions such as MLGRD, LWSC and ZNPHI had more than one respondent to help in answering some of the questions. This study grouped these institutions as the Disaster Management Authority, Public Service Providers for Water Supply and Sanitation, Local Government Authorities, Health Institutions in Peri-Urban Areas and Public Health Research Institutions, accordingly. In order to get a comprehensive understanding of society's perspective on the relevant developing concerns, the writers also engaged the community from the Kanyama complex. For this specific data collection, a focus group discussion was chosen as the mode of inquiry.

After collecting this qualitative data, the authors carried out an open coding analysis. In this study, pieces of data that summarized abstract ideas based on analytical findings were given tentative labels, or conceptual features, by the authors after reading through the data repeatedly.

After carefully analyzing these pre-existing conceptual elements, the authors developed inferred cluster labels for linked conceptual elements, which is referred to as an axial coding strategy. Emergent concerns were assigned to these cluster labels. Further, the observed occurrences from these results were characterized using the recognized emergent concerns and their associated conceptual characteristics.

3 RESULTS AND DISCUSSION

The National Disaster Management Policy of 2015 governs the use of resources pre-disaster, during disaster and post disaster phases. It explicitly states the procedures to follow concerning disasters that includes drought, floods, epidemics and pests, which are the common disasters in Zambia. It acknowledges the need for water and sanitation services during a disaster, but merely mentions the need for these services to be delivered and not how they should be delivered. The out lined procedures for the various disasters are generalized and not specific to a type of settlement (Mudenda et al. 2022b). The case of Kanyama peri-urban area, in Zambia, presented the authors with an in-depth perspective of emergent issues associated with flooding disaster management and Water, Sanitation and Hygiene (WASH) in peri-urban areas. Following a Straussian Grounded Theory approach, the authors establish these emergent issues to consist of problems in existing prevention, preparedness and response disaster management mechanisms in coherently addressing flooding disasters and public health aspects for peri-urban livelihoods. It was established that characteristic of these emergent issues is the inadequacies in the coherence of institutional disaster and public health management specific to peri-urban areas, under flooding disaster management. These emergent issues are inherent to the predominance of pit latrines and problems associated with peri-urban areas classified as informal settlements and are categorized in this study to include: a) sanitation facilities; b) service delivery; c) informal settlement problems; d) societal attitudes and behaviour; e) responsiveness of authorities; and f) community and stakeholder engagement (Figure 2). The authors present an array of observed phenomena associated with these emergent issue categories and their effects. Further, the authors discuss the changes needed in flooding disaster management in coherently addressing flooding disasters and WASH aspects for peri-urban livelihoods, in the case of Zambia or societal context infringed on the characteristics of this case study and emergent issues established.

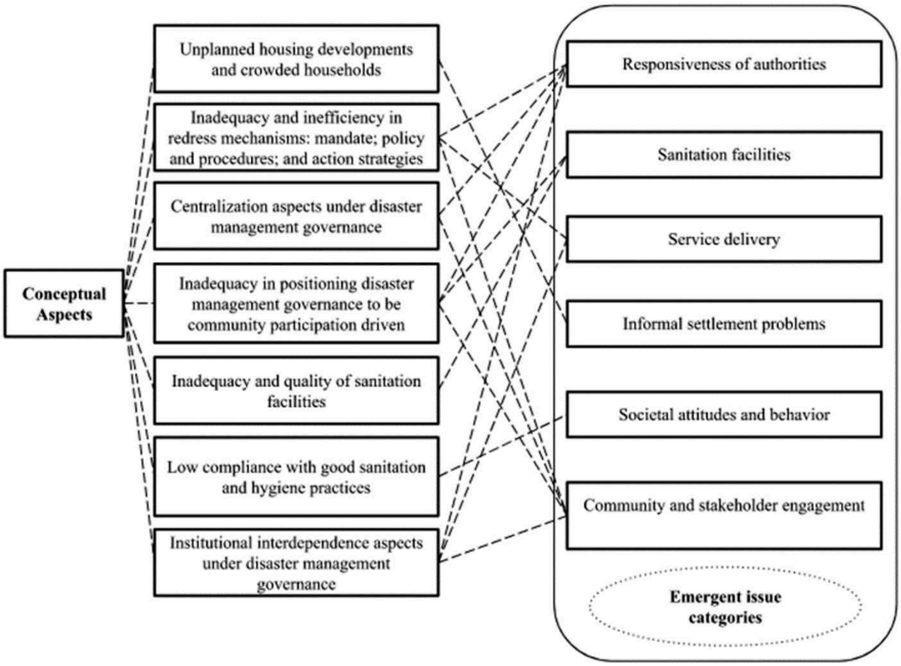

Figure 2. Emergent issues and associated conceptual aspects.
(source: author)

3.1 *Phenomenon 1: Cultural behaviour of public-institutions towards flood disaster management in peri-urban areas*

The results of this study indicated that in the absence of clearly defined and specific institutional policy and mandate for coherently addressing peri-urban flooding disasters and public health aspects, there is a culture of relaxed and reactive responsiveness by government institutions (Figure 3). Institutions that take "surge capacity" and "cascading" reactive approaches indicate inadequacies in preparedness for response and resilience to flooding disasters and public health effects concerns. In this context, cascading can mean a variety of things, such as waiting until an emergency response is required or being unprepared to provide an emergency response in the case of a flooding disaster. Surge capacity methods, on the other hand, pertain to situations where these institutions lack a strategic plan for responding in terms of the additional technical and financial capacity needed in the case of a disaster. In light of the fact that cascade and surge capacity methods are reactive techniques, it follows that relying on them forces these institutions to postpone taking action or responding to emergencies involving public health concerns.

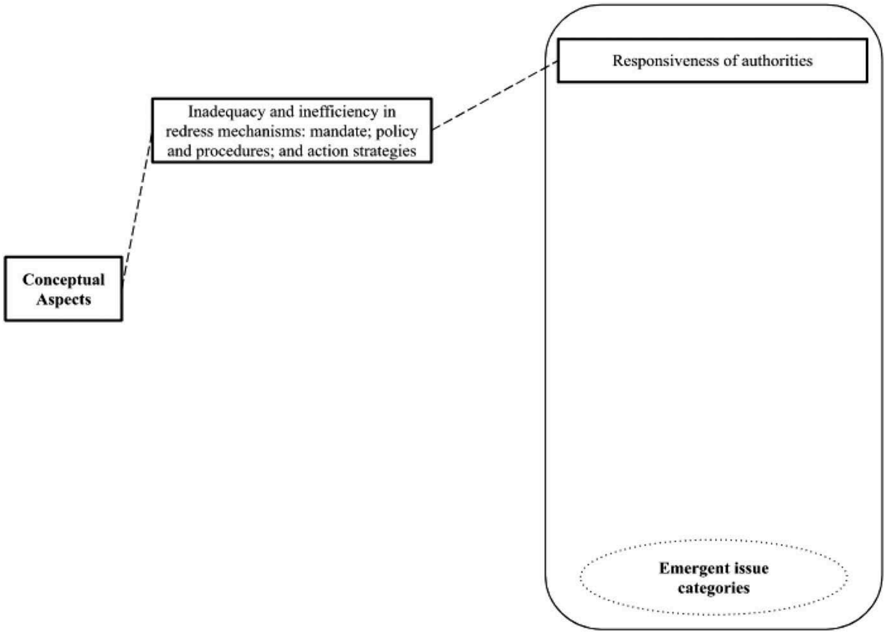

Figure 3. Phenomenon 1: Cultural behavior of public-institutions towards flood disaster management in peri-urban areas.
(source: author)

3.2 *Phenomenon 2: Viability of flood disaster management governance being non-specific to peri-urban areas*

The viability of flood disaster management governance being non-specific to peri-urban areas is an observed phenomenon indicated by the results of the emergent issues established in this study (Figure 4).

Problems with informal settlements, which are mostly caused by the lack of original planning for these communities, impede improvements in the supply of water and sanitation services. Another problem is overcrowding in homes, which has a "ripple effect" on other pressing matters like service provision and sanitary amenities. In this study, the terminology ripple effect implies the occurrence of one aspect leading to the occurrence of another. The overwhelming dependence on pit latrines is linked to the problem with sanitation infrastructure in peri-urban settings. The inability of constructed pit latrines to accommodate the number of people per family is one of the main issues with these facilities. Faecal matter overflows during the rainy season and their groundwater is contaminated as a result of inadequate pit latrine liners, both of which are issues with the quality of household-built pit latrines in peri-urban regions. The execution of "retro-fit" pit latrine design and construction standards must give way to peri-urban-focused strategic initiatives.

Some of the problems associated with the viability of flood disaster management governance are connected to the authorities' responsiveness and service provision. In peri-urban settings, the adequacy and quality of solid waste management, water supply and sanitation services are major concerns. Following traditional norms and methods, in peri-urban settings, used for service delivery mainly in metropolitan settings is the cause of these deficiencies. Further, policy and procedure are related to how responsive the authorities are and this research has found that in the case of peri-urban areas, the processes used in metropolitan areas are nearly completely ineffective. In Kanyama and other peri-urban settings, there was little effort put towards advancing improvements in solid waste collection. Low investment was found to exist in the sub-sector of solid waste management, particularly in peri-urban regions.

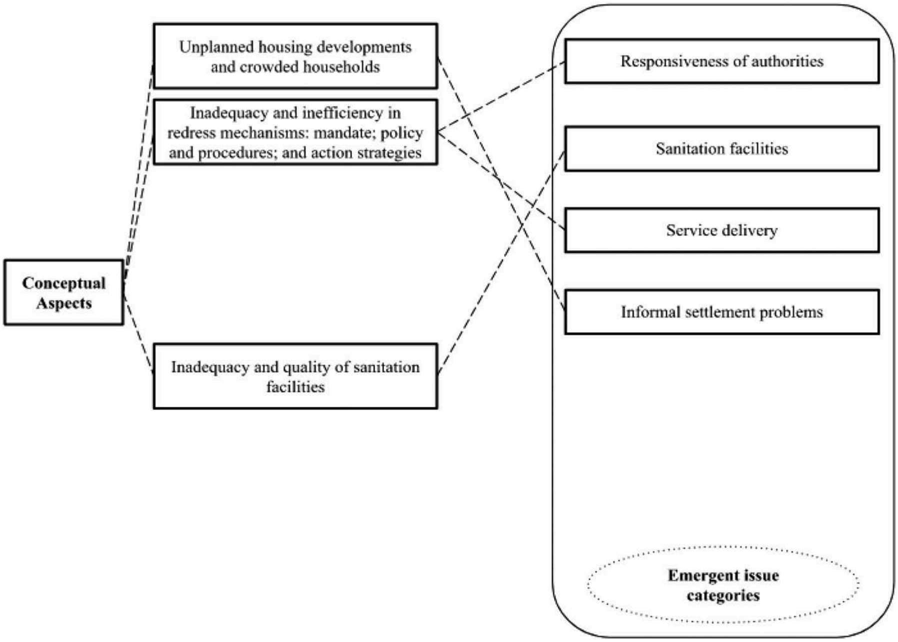

Figure 4. Phenomenon 2: Viability of flood disaster management governance being non-specific to peri-urban areas.
(source: author)

In order to collect and dispose of solid waste, a general strategy was utilized, embracing methods and techniques that are often used in urban settings but that don't appear to work as well in peri-urban ones. For instance, it was stated that there was a need to improve solid waste collection while making a significant concession to the garbage collection vehicles, such as using enclosed trucks for long hauls instead of tippers or unconventional garbage collection vehicles, which in turn contributed to the problem of odour and spilling of solid waste. The inadequate quantity of waste bins and poor residential rubbish collection were also flagged as issues.

These results make it necessary to modify flooding disaster management policies and practices to be more tailored to peri-urban settings and water, sanitation and hygiene aspects for such development areas. The following strategies are proposed in this paper for the relevant authorities to use in peri-urban communities: (a) involvement in the construction of household pit latrines; (b) implementation of inter-modal garbage collection systems that take advantage of also improving standards in each individual mode (wheelbarrows, carts, trucks, etc.); and (c) intensification of regular garbage collection and placement of skip bins, for example.

3.3 *Phenomenon 3: The effect of interdependencies among public institutions in flood disaster management governance*

Results showed that you can't talk about disaster management governance without talking about institutional interdependencies (Figure 5). Further, you can't talk about interdependencies without bringing into discussion the detrimental effects of inadequacy and inefficiency in redress mechanisms of one institution affecting another's responsiveness and service delivery (ripple effect). For instance, in this study, it was determined that Kanyama compound's provider of public water and sanitation has a response plan in place for handling emergencies. The reliance on the Local Government Authority's responsiveness for it to implement its emergency response plan in disaster preparedness or response, however, renders this weak on its own.

In all institutions (within the purview of this study), with the exception of the Water Supply and Sanitation Public Service Provider, prevention/mitigation, preparedness and response redress mechanisms are negatively impacted by the absence of disaster management policy specifically addressing flooding disasters and public health aspects in peri-urban settings. Although the Water Supply Sanitation Public Service is not directly impacted by this conceptual aspect of the discussed emergent issue, failures in the preparedness of the Local Government and Disaster Management Authorities have a ripple effect that negatively impacts their preparedness and response to emergency sanitation. This is following the centralization of prevention/mitigation and preparedness for response to Local Government and Disaster Management Authorities.

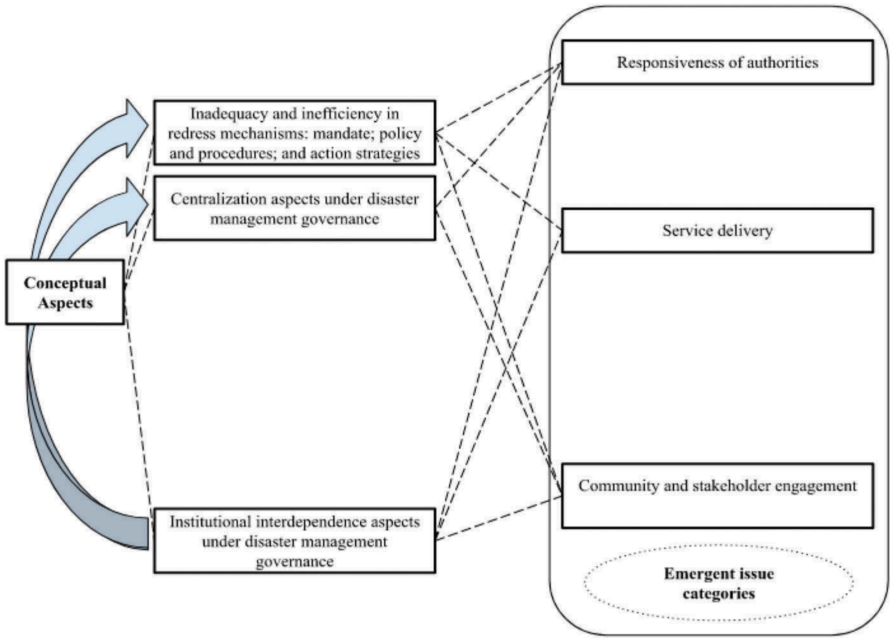

Figure 5. Phenomenon 3: The effect of interdependencies among public institutions in flood disaster management governance.
(source: author)

With centralization under disaster management governance, the most significant conceptual component is dependent on the interdependency among the Disaster Management Authority and other institutions. Community and stakeholder participation is an emerging concern. The study's conclusions show that all flooding disasters are coordinated by the Disaster Management Mitigation Unit (DMMU), that they adhere to current parliamentary laws and regulations and that they primarily rely on multi-sectoral high-level national pandemic meetings. The detrimental ripple effects seen by all other institutions, with the exception of the Public Health Research Institution, are what distinguish the basic centralization problems. This is due to the link between the Public Health Research Institution and the Disaster Management Authority being primarily dependent on the former in order to improve preventative planning and readiness for the latter's reaction action procedures. The results of this study also show that health institutions do not actively engage stakeholders, which further explains why stakeholder involvement is limited in situations where time-sensitive measures must be made.

Interdependence among these institutions is inevitable. However, this study presents an argument that there is a need for decentralization of prevention/mitigation and preparedness for response and community and stakeholder engagement, authority and capacity based on a shift in institutional mandate and policy for coherently addressing flooding disasters and public health aspects in peri-urban settings.

3.4 *Phenomenon 4: The necessity of community participation as part of flood disaster management governance*

There are a number of detrimental primary and ripple effects when little effort is made in positioning disaster management governance to be community participation driven (Figure 6). These ripple effects are explained by the inadequacies and inefficiencies felt in the other three labeled conceptual aspects (Figure 6).

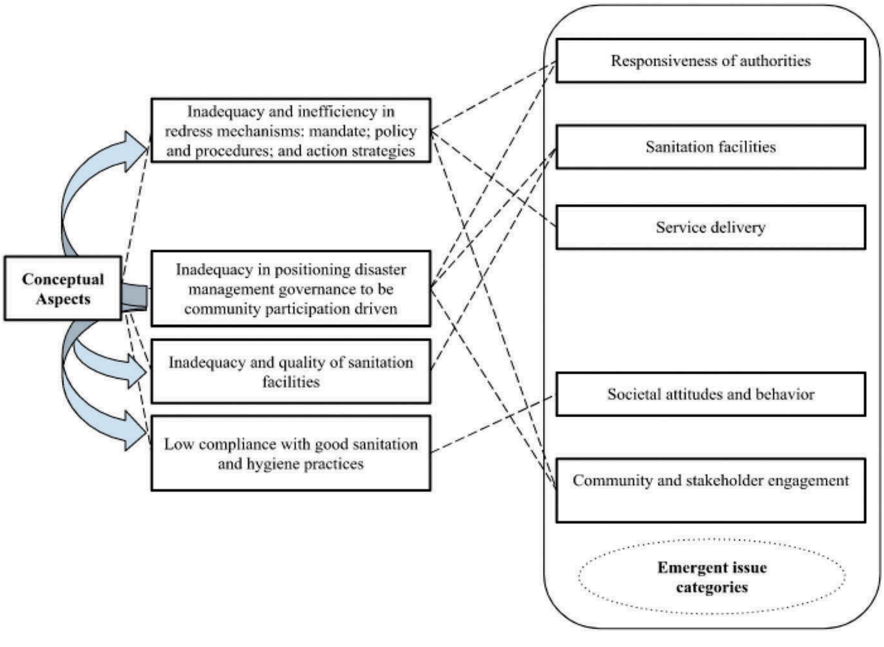

Figure 6. Phenomenon 4: The necessity of community engagement as part of flood disaster management governance.
(source: author)

In order to address the community's needs and difficulties with regard to flooding disasters and public health concerns, relevant authorities made very little effort to include and engage them in preventative sanitation responses. It was said that other than education, awareness and chlorine delivery, they are not given the chance to actively participate in stakeholder engagement and institutional sanitation improvement related initiatives. This has a detrimental effect on the responsiveness of authorities, household construction of sanitation facilities, water supply and sanitation service delivery, solid waste (garbage) collection service delivery, societal attitudes towards institutional interventions and community and stakeholder engagement. Each emergent issue is described by its associated conceptual aspect illustrated in Figure 6. Given the issues raised in Phenomenon 2, these communities lack the technical know-how to construct high-quality pit latrines on their own. In addition to the requirement for community involvement in institution-related activities aimed at coherently resolving flooding catastrophes and public health problems, authorities must be responsive. Respondents recommended community plan opportunities that give ownership to the inhabitants of these communities in order to contribute to greater good social behavior and attitudes in response to the outcomes of the focused group discussion.

Therefore, there is a need to orient flood disaster management governance to be more community participation inclusive.

4 CONCLUSION

This study concludes by bringing to the fore four key phenomena established from the emergent issues needed to be enhanced in order to improve disaster management with adaptive robustness for peri-urban areas. These include: (a) cultural behaviour of public institutions towards flood disasters in peri-urban areas; (b) viability of flood disaster management being non-specific to peri-urban areas; (c) the effect of interdependencies among public institutions in flood disaster management governance; and (d) the necessity of community participation as part of flood disaster management governance. Further, these observable phenomena help explain consequential paradigms that provide a premise for decision-makers, policy makers, and planning authorities to structure adaptive implementation strategies to address peri-urban concerns with regards to flooding disasters and public-health.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Market environmental factors hindering small construction contractors in successful bidding for infrastructure projects

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ABSTRACT: With the ever-changing construction business environment, small contractors must have the requisite knowledge to effectively secure projects to remain in business. This study focuses on identifying the market environmental factors hindering the successful bidding for small contractors. The research was conducted in Blantyre-Malawi using questionnaire survey. The population was the registered contractors in building and civil category, belonging in class 1 to 4 of company classification in Malawi. The sample size of 159 was selected from 265 contractors by stratified sampling. The results from 126 feedbacks were analyzed by mean score; spearman's correlation coefficient; frequencies and ANOVA. The top ranked factors are lack of construction associations; increased environmental compliance; lack of mentorship; and increased pandemic effects respectively. The transient nature of this problem in modern times makes the results informative to contractors in Malawi, replication of the study in other parts of the world would be essential for comparative analysis.

Keywords: Small contractor, bidding, competition, Malawi, Infrastructure

1 INTRODUCTION

Infrastructure projects have significant impacts in economic development and social wellbeing (Neil, 2010). In provision processes, small construction contractors occupy an important place in project implementation and delivery of infrastructures (Johari, et al., 2019). Competitive bidding is explained as the process of infrastructure delivery in which a number of potential construction contractors rivalry compete for projects (Lyn, 1992). Competitive bidding is done by submitting the intent to undertake the projects on a particular price within a particular period of time and by specifying all particulars proving the ability to execute the project being competed for (Lyn, 1992). In their study, (Kulemeka, et al.,2015) noted that the project owner that maybe individual, private or public institutions benefit from this process as the work is done at a competitive and reasonable price with smooth and secured implementation. It is through competitive bidding that new emerging contractors appear as well as new specializations. The construction industry in general grows through competitive bidding While (Douh, 2015).

Small contractors in Malawi are many, and very little research has been done about their competitive bidding status (ACF, 2019). In addition, if contractors do not get jobs for a long time, they may be involved in deceptive acts to get contracts. Otherwise, they are deregistered

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from the business. The purpose of this study is to investigate the market environmental hindering small construction contractors in competitive bidding for infrastructure projects in Malawi.

Researchers and scholars have shown their attention on performance of contractors in project delivery (Ali, et al., 2020). Sub-Sahara african research projects concentrated on the growth of the construction industry and contract (Kulemeka, et al., 2015). Identifying the inhibiting factors in competitive bidding is crucial to contractors, construction industry as well as the academic body of knowledge.

2 LITERATURE REVIEW

The ability to compete for some contractors is driven by the willingness to participate in a particular type of bid considering the specification, the price and the source of information on tender as well as the past experience on similar projects (Raju, et al., 2015). There are numerous factors that influence the failure of companies in competing for infrastructure projects. These factors may be classified depending on the objective and the nature of the study.

The issue of market environmental factors inhibiting the successful bidding for small contractors is not a recent and local issue. Different researchers investigated the same at global extent and factors were gathered. The most discussed factors are negative effects of globalization; lack of access to markets; increased demand for environmental sustainability compliance; limited market size in the category of small contractors; attitudes on foreign services; poor image of small and medium enterprises; increased pandemic effects; geographic coverage; lack of construction associations; lack of mentorship; and contractor's risk attitude.

The increased demand for environmental sustainability compliance in construction sector impacts negatively the financial performance of small contractors in Nigeria (Olakunle, 2015). As in other countries, Malawi enhances environmental compliance from company registration processes to the project implementation (NCIC, 2015).

In south africa, researches show the positive impacts of mentorship on the bidding performance of small contractors (Mofokeng & Thwala, 2012). The lack of mentorship on small contractors reduces their chances not only to win the bid, but their development processes (Hauptfleisch & Verster, 2007).

The pandemic containment measures negatively impact the construction industry, especially small contractors (Biswas, et al., 2020). Delays in completing the projects and reduction of employees have made construction players vulnerable in terms of capacity and recovery as noted by (Muzaffar, et al., 2021).

The lack of Contractors associations impact negatively the companies and individuals through lack of shared experience; knowledge transfer; mutual cooperation; enhancing competitiveness and raising voice for each other (Elijah, et al., 2020).

The contractor's risk attitudes influence the ability of contractors to bid for particular types of projects (Adeleke, et al., 2017). The image of the company is more important in competition and performance for it draws attention of customers to provide a competitive advantage and market support (Aranda, Gomez, & Molina, 2015). According to (Sharmilee & Muhammad, 2016), construction companies brand their image through past experience on completed projects; risk attitudes and contract disputes management. Moreover, with the development in technology and media, digital marketing is also an emerging key to market the image on global trends (Anne Mumbua, 2020).

3 RESEARCH APPROACH AND METHODS

3.1 *Research area and approach*

The research on small scale contractors was undertaken in the commercial city of Blantyre in Malawi in March 2022. This study area is the business hub and the second largest city in Malawi with highest number of small-scale contractors. The foregoing characteristics presented themselves as a candidate for the study area. Having established the variables of research through a literature review it followed that a quantitative approach was best suited to this investigation to examine them on selected sample (Apuke, 2017).

3.2 *Population sample and size*

With the study population of 265 contractors, a confidence level of 95 and 0.05 as precision, a sample size of 159 from registered construction contractors with the National Construction Industry Council was computed using Yamane's formula (1967). As follow:

$$\eta = \upsilon\left(1 + \upsilon e^2\right)^{-1} \text{ where } \eta = \text{sample size; } v = \text{population; } e = \text{margin error} \tag{1}$$

3.3 *Data collection technique*

After pre-testing, the survey questionnaire was issued to construction firms to elicit data. Furthermore, seven attributes were used to characterize the sample, namely: company category; company size; annual turnover; company experience; respondent's experience; respondent's qualification and respondent's training acquired. A total of 126 responses were obtained.

3.4 *Analysis of results*

The data analysis was done by statistical functions of Spearman correlation coefficient; mean score and Kruskal and Wallis analysis of variance for non-parametric data. To measure the weighted mean, each variable that has to be aggregated was given a weight in the form of an ordinal value in the survey. The equation used to determine the weighted average of factors influencing the failure of small contractors in competitive bidding is

$$\xi = \frac{\sum_{i=1}^{w} \lambda_i(x_i)}{\sum_{i=1}^{p}(x_i)} \tag{2}$$

Where xi=observation; λi=weight of observation; w=5-point Likert scale; p=the number of respondents and i=integral numbers.

After computing the weighted mean, the values were construed to correspond to the ratings provided in the questionnaire. These are strongly disagree; disagree; neutral; agree and strongly agree. This was done to convert the continuous numbers into unique classes as discussed by (Rennolls, 1986). The weighted mean values were then linked to the respective levels as follow:

Level one $1.00 \leq \gamma \leq 1.50$; Level two $1.50 \leq \gamma 2.50$; Level three $2.50 \leq \gamma 3.50$; Level four $3.50 \leq \gamma \leq 4.50$ and Level five $4.50 \leq \gamma \leq 5.00$

In order to examine the difference in ratings, the analysis of variance was done based on company and respondent's attributes and variables. The attributes (ki) were company category (k1=3); company size (k2=3); annual turnover (k3=3); company experience (k4=3); respondent experience (k5=3); respondent highest qualification (k6=2); and respondent's level of training acquired (k7=4). To verify the variation of attributes within a sample and to decide whether variables should be analyzed based on the groups (Ghasemi & Zahediasl, 2012), the following formula was used for statistic H test:

$$H = \frac{12}{N(N+1)}\left[\frac{\sum_{i=1}^{k} T_i^2}{n_i} - 3(N+1)\right] \tag{3}$$

Where N=total number, n=number in the *i-th* group and Ti= total sum of ranks in the *i-th* group for data without ties. For data with ties, H was divided by the following formula to apply correction:

$$\Delta = 1 - \frac{\sum_{i=1}^{G}\left(t_i^3 - t_i\right)}{N^3 - N} \tag{4}$$

Where G= number of groups of tied ranks and ti= number of tied values within the i^{th} group

The Spearman's correlation coefficient ρ was used to analyze the degree of association between company and respondent's attributes and the variables to be studied. Since the data are ordinal, the following formula was used:

$$\rho = 1 - \frac{6\sum_{i=1}^{N} D_i^2}{n(n^2 - 1)} \tag{5}$$

Where $Di = R1i - R2i$ with $R1i$ being the rank of i in the first group and $R2i$ being the rank in the second group of data and n is the number of pairs of observations.

The results were computed and linked to the following range of relationship (ρj, for j is 1 t0 5): $\pm 0.00 \le \rho 1 \le 0.19$ is a very weak relationship on positive or negative range; $\pm 0.20 \le \rho 2 \le 0.39$ weak relationship on positive or negative range; $\pm 0.40 \le \rho 3 \le 0.59$ moderate relationship on positive or negative range; $\pm 0.60 \le \rho 4 \le 0.79$ strong relationship positive or negative as well as $\pm 0.80 \le \rho 5 \le 1.00$ to be a very strong relationship on positive or negative range

4 RESULTS AND DISCUSSION

The results from questionnaire characteristics of respondents shown above demonstrate distributions which are dichotomy, unimodal, slightly normal, negatively and positively skewed. The foregoing distributions made it essential that analysis of variance be conducted to determine if the groupings of the company attributes had influenced their responses.

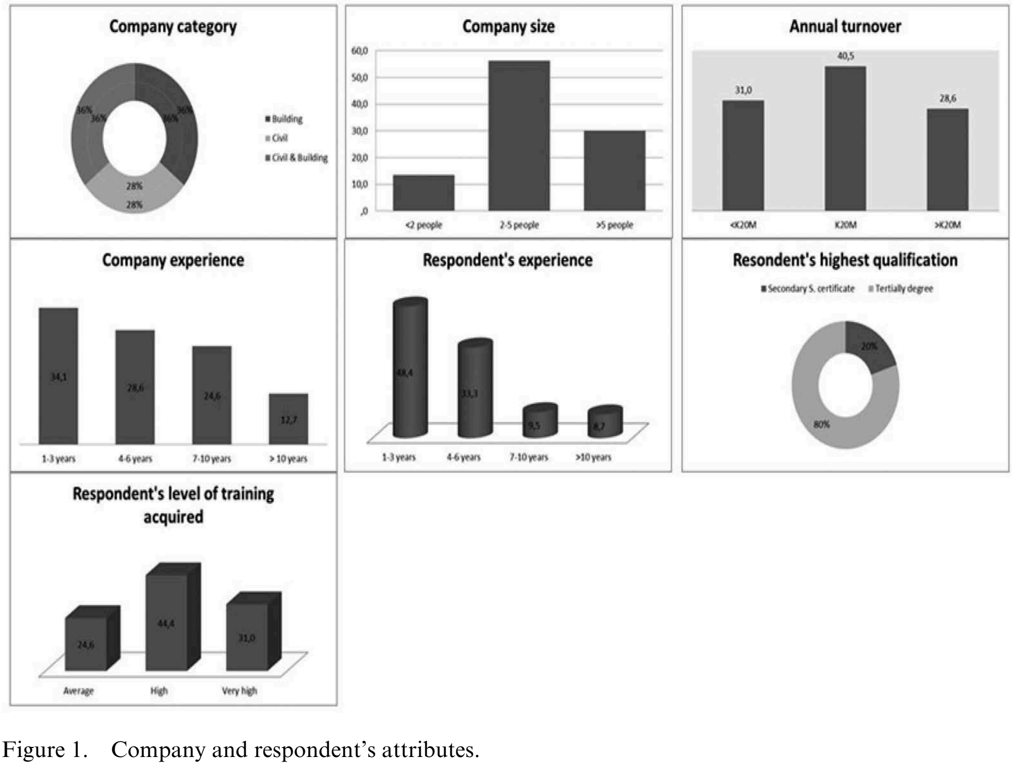

Figure 1. Company and respondent's attributes.

The results from analysis of variance in Table 1 show that many variables are very significant with respect to respondent's groupings at p≤0.05. This informs that the company attributes had impacted the rating of variables in the questionnaire. This made the severity indices to be computed and analyzed on basis of the company attributes to take on board the influence of the effects of the grouping in data collection.

Table 1. Kruskal-Wallis test one-way analysis of variance.

		Company characteristics						
		Company category	Company size	Turnover	Company experience	Respondent's experience	Respondent's qualification	Respondent's training acquired
Factors of research	Static symbol	*df=2*	*df=2*	*df=2*	*df=3*	*df=3*	*df=1*	*df=2*
Negative effects of globalization	χ2	0.601	3.252	18.475	2.185	26.620	2.212	3.710
	p	0.741	0.197	0.001	0.535	0.001	0.137	0.156
Lack of access to market	χ2	0.659	7.872	49.051	16.491	55.425	30.714	28.720
	p	0.719	0.020	0.001	0.001	0.001	0.001	0.001
Demand for environmental compliance	χ2	3.045	10.969	67.349	18.591	42.783	35.693	50.289
	p	0.218	0.004	0.001	0.001	0.001	0.001	0.001
Limited market size in class	χ2	0.784	1.461	72.961	23.675	39.128	37.489	57.341
	p	0.676	0.482	0.001	0.001	0.001	0.001	0.001
Attitude on foreign services	χ2	0.795	9.804	78.791	26.251	31.951	17.903	62.957
	p	0.672	0.007	0.001	0.001	0.001	0.001	0.001
Poor image of SMEs	χ2	1.351	17.641	42.610	9.558	53.412	9.331	27.272
	p	0.509	0.001	0.001	0.23	0.001	0.002	0.001
Increased pandemic effects	χ2	5.461	9.961	64.231	16.423	37.774	39.946	49.224
	p	0.220	0.007	0.001	0.001	0.001	0.001	0.001
geographical coverage	χ2	2.255	8.814	45.206	25.005	27.108	22.559	69.787
	p	0.065	0.012	0.001	0.001	0.001	0.001	0.001
Lack of construction associations	χ2	4.154	16.840	61.278	14.989	52.524	54.111	46.688
	p	0.324	0.001	0.001	0.002	0.001	0.001	0.001
Lack of mentorship	χ2	3.030	16.677	62.266	13.021	53.999	44.264	36.075
	p	0.125	0.001	0.001	0.005	0.001	0.001	0.001
Contractor's risk attitudes	χ2	1.073	13.787	83.352	15.052	71.071	46.671	68.280
	p	0.585	0.001	0.001	0.002	0.001	0.001	0.001

df=degree of freedom, for all data n=126, value for p≤0.05 is significant for two tailed test

The Table 2 represents the findings based on company category, size and experience. Based on company experience, the results demonstrate high ranking for the lack of construction contractors' associations in the group of companies ranging between one- and three-year' experience with severity index of 3.42. The group having between four to six years' experience adds the increased pandemic effects with severity index of 3.39. The group ranging between seven to ten years' experience highlights geographic coverage with severity index of 2.68 while the lack of mentorship is the most ranked by the group of contractors with more than ten years' experience. for the purpose of maximizing the benefits from mentorship provision to both contractors and construction industry, the involved parties should work hand in hand to identify the needs and impacts as well as creating a favorable environment for training delivery.

On contractor category side, building contractor's category highly ranked increased pandemic effects with severity index of 3.3. Civil contractor's category highly ranks the same as building with severity index of 3.27, while the civil and building group reveals the demand for environmental sustainability compliance and the lack of mentorship with 2.72. For companies to better abide with compliance in environmental sustainability, the environmental practices and requisites should be considered in planning as well as in bidding and pricing. On the company size, the group of companies having below 2 employees and the one having between 2 to 5 highly ranked increased pandemic effects (3.47and 2.93). The lack of construction associations is the most rated by the group having more than five employees with 3.61. There is a need of construction associations to defragment companies in order to be more interactive and raise one voice for their growth and the development of construction industry.

Table 2. Severity indices by company category, company size and experience.

Factors of research	Company category (0)*	Company category (1)*	Company category (2)*	Company size (0)*	Company size (1)*	Company size (2)	Company experience (1)	Company experience (2)	Company experience (3)	Company experience (4)
Negative effects of globalization	1.47	1.60	1.69	1.06	1.60	1.71	1.35	1.61	1.84	1.63
Lack of access to markets	1.96	1.91	2.11	1.59	2.25	1.66	1.37	2.36	2.39	2.00
Demand for environmental compliance	3.13	3.18	2.72	3.71	2.82	3.13	3.40	3.17	2.42	2.94
Limited market size	2.51	2.56	2.17	2.88	2.30	2.45	2.47	3.06	1.65	2.38
Attitude on foreign services	2.69	2.56	2.42	3.47	2.34	2.58	3.30	2.53	1.61	3.50
Poor image of SMEs	2.11	1.96	2.31	1.59	2.54	2.58	1.63	2.44	2.32	2.25
Increased pandemic effects	3.31	3.27	2.67	3.76	2.93	3.16	3.28	3.39	2.61	3.00
Geographic coverage	1.67	1.58	1.94	1.24	2.00	1.39	1.30	1.42	2.68	1.63
Lack of construction associations	3.13	3.20	2.69	3.47	2.62	3.61	3.42	3.39	2.13	2.94
Lack of mentorship	3.20	3.22	2.72	3.53	2.70	3.55	3.33	3.19	2.58	3.06
Contractor's risk attitude	1.38	1.49	1.81	0.76	1.79	1.42	1.09	1.31	2.29	1.81

* (0): building category; (1): civil category; (2): building and civil category
* 0): company with one employee; (1): 2-5 employees; (2): above 5 employees
* (*(1): experience between 1-3 years; (2): 4-6 years; (3): 7-10 years; (4): experience above 10 years

In Table 3, represents the results of indices according to annual turnover and respondent's experience. The group of companies having annual turnover below 20 million highly rated the lack of mentorship; lack of construction associations; increased pandemic effects; attitude on foreign services and demand for environmental sustainability compliance with the same highest severity index of 4.00 each. The group of companies with 20 million turnover ranked the lack of construction associations with the severity index of 3.35 while the group having above

20 million of average annual turnover rated the lack of access to market with severity index of 3.00. On experience side, the group of respondents with experience ranging between one and three years indicated the increased pandemic effects with severity index of 3.31. The group ranging between four to six years' experience ranked the lack of construction associations with severity index of 3.81. The group ranging between seven to ten years' ranked the contractor's risk attitude and negative effects of globalization with 3.25 each. The group of respondents having more than ten years' experience ranked the lack of access to markets with severity index of 3.55. To improve access to market, contractors should review and improve relation and access to information. Information gathering, social integration and network building can facilitate small construction companies to address different hurdles and restrictions.

Table 3. Severity indices by company annual turnover and respondent's experience.

Factors of research	Turnover (0)*	Turnover (1)*	Turnover (2)*	Respondent's experience (1)	Respondent's experience (2)	Respondent's experience (3)	Respondent's experience (4)
Negative effects of globalization	1.00	2.02	1.58	1.41	1.52	3.25	0.91
Lack of access to markets	1.00	2.02	3.00	2.25	0.95	2.83	3.55
Demand for environmental compliance	4.00	2.98	2.06	3.25	3.45	0.83	2.64
Limited market size	3.00	3.06	0.89	2.82	2.62	1.08	0.91
Attitude on foreign services	4.00	2.45	1.17	2.52	3.29	1.50	1.18
Poor image of SMEs	1.05	2.43	2.81	2.75	0.98	2.25	2.73
Increased pandemic effects	4.00	3.08	2.19	3.32	3.40	1.67	2.45
Geographic coverage	1.00	1.47	2.83	1.49	1.38	2.92	2.91
Lack of construction associations	4.00	3.35	1.53	3.18	3.86	1.83	0.36
Lack of mentorship	4.00	3.00		2.95	3.81	2.50	1.55
Contractor's risk attitude	0.31	1.55	2.17	1.44	0.79	3.25	3.09

*(0): Turnover below 20million; (1): turnover equal to 20 million; (2): turnover above 20 million
*(1): Experience between 1-3 years; (2): 4-6 years; (3): 7-10 years; (4): experience above 10 years

Table 4. Severity indices on respondent's level of qualification and level of training.

Factors of research	Respondent's qualification (1)*	Respondent's qualification (2)*	Level of training (2)*	Level of training (3*)	Level of training (4*)
Negative effects of globalization	2.00	1.48	1.29	1.68	1.67
Lack of access to markets	3.20	1.68	1.13	1.93	2.74
Demand for environmental compliance	1.76	3.35	3.61	3.36	2.10
Limited market size	0.80	2.82	2.61	3.14	1.23
Attitude on foreign services	1.52	2.82	3.68	2.96	1.10
Poor image of SMEs	2.80	1.94	1.16	2.21	2.72
Increased pandemic effects	1.92	3.41	3.48	3.45	2.33
Geographic coverage	2.72	1.47	1.13	1.07	3.10
Lack of construction associations	0.84	3.57	3.71	3.59	1.69
Lack of mentorship	1.6	3.44	3.61	3.32	2.28
Contractor's risk attitude	3.04	1.17	0.42	1.29	2.79

*(1): Qualified with Secondary certificate; (2): Tertiary degree holders
*(2): Average level of training; (3): High level of training; (4): Very high level of training

Table 5. Correlation of company characteristics with the variables of research.

Factors of research	Static symbol	contractor's attitude	effects of globalization	Lack of access to markets	environmental compliance	limited market size in class	attitude on foreign services	Poor image of SMEs	increased pandemic effects	geographical coverage	Lack of construction associations	Lack of mentorship
company	Φ	0.093	0.069	0.052	-0.108	-0.049	-0.079	0.055	-0.170	0.093	-0.104	-0.126
category	p	0.151	0.221	0.281	0.113	0.291	0.189	0.270	0.028*	0.151	0.122	0.081
company	Φ	-0.02	0.115	-0.077	-0.062	-0.054	-0.109	-0.142	-0.014	-0.068	0.127	0.121
size	p	0.492	0.100	0.196	0.245	0.275	0.112	0.057	0.439	0.224	0.078	0.089
Average	Φ	0.817	0.127	0.626	-0.733	-0.558	-0.789	0.545	-0.713	0.557	-0.695	-0.697
turnover	p	0.001*	0.078	0.001*	001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
company	Φ	0.328	0.101	0.266	-0.323	-0.176	-0.377	0.207	-0.283	0.284	-0.285	-0.269
experience	p	0.001*	0.130	0.001*	0.001*	0.025*	0.001*	0.010	0.001*	0.001*	0.001*	0.001*
respondent	Φ	0.142	0.087	0.021	-0.227	-0.503	-0.092	-0.322	-0.278	0.330	-0.157	0.005
experience	p	0.057	0.166	0.409	0.005*	0.001*	0.153	0.001*	0.001*.	0.001*	0.040*	0.479
Respondent's	Φ	0.611	-0.133	-0.496	0.534	0.548	0.378	-0.273	0.565	-0.425	0.658	0.595
qualification	p	0.001*	0.069	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
level of training-	Φ	0.739	0.029	0.479	-.606	-0.475	-0.697	0.446	-0.567	0.616	-0.580	-0.536
ing acquired	p	0.001*	0.375	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001

φ= Spearman's correlation coefficient, for all data n=126, *p≤0.05 is significant for two tailed test

Table 4 presents results of respondents' level of qualification and level of training. The group of respondent's with secondary certificates ranked the lack of access to markets with severity index of 3.2 while the group having tertiary degree ranked the lack of construction contractors' association with severity index of 3.57. Regarding the level of training, the group of respondents with average level of training rated the lack of construction associations with severity index of 3,71. The group with high level of training rated the same as the first with severity index of 3.59 while the group with very high level of training rated geographic coverage with 3.10.

Table 5 presents results of correlation between company characteristics and the market environmental factors. The relationship of majority of the research variables on environmental factors with company category and company size has inverse relation that is not significant at p ≥.05 except for increased pandemic effects. However, the relationship between company attributes for average turnover, company experience, respondent experience, highest qualification, training acquired with variables of research on environmental factors were strong and significant at p≥.05. From the foregoing it shows that the environmental factors have an effect on bidding of the construction contractors.

5 CONCLUSION

The study aimed at identifying the market environmental factors hindering small construction contractors in competitive bidding in City of Blantyre, Malawi. The variables and company attributes were scrutinized and the questionnaire was developed and distributed to small contractors in the study area. The analysis of feedback demonstrates with great consistency that variables are significant based on the groups of samples. It implies that the environmental factors have an effect on bidding of the construction contractors based on the contractors attributes. The main factors highly ranked in all groups are lack of construction contractors associations; increased environmental compliance; lack of access to markets; lack of mentorship and increased pandemic effects. The salient importance of the findings from the research is practically informative to small contractors; construction industry; stakeholders; researchers as well as academic field.

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Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Spatio-temporal variance; infrastructure and urban development drive in Minna North-Central Nigeria

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ABSTRACT: This paper sought to analyse the City's land use changes between 1999 and 2019 using a spatio temporal analysis and change detection method. The research also simulate land-use changes in Minna for 2029, the locational attributes of various infrastructure were also appraised using the Nearest Neighbour analysis through a collection of infrastructure coordinates in the City of Minna. An assessment of the roles of city infrastructures in urban growth. Spatio-temporal image processing and analysis, mosaicing, and artificial neural networks project the extent of urban growth between 1999 and 2019 while simulating the growth for ten years to 2029. Conclusively, the City of Minna depicts an urban environment without proper planning and standards while providing the opportunity for a liveable city. The city is increasing and providing critical infrastructure, but spatial distribution is lopsided, and this must be adequately and urgently addressed for sustainability and liveability.

1 INTRODUCTION

Three significant aspects characterize urbanization: (1) the expansion of urban areas and their increasing complexity; (2) the development of a wide range of urban outcomes in various contexts; and (3) the need to analyze urbanization processes and not just urban form. The critical urban theory has recently introduced the concept of planetary urbanization to address a wide range of urban transformations that have called into question many of the fundamental assumptions and certainties of urban research. In addition, this includes a variety of phenomena that extend the urban's territorial reach into the seemingly 'non-urban realm' (Brenner and Schmid, 2014, Brenner and Schmid, 2015).

As a result of these processes, urban development patterns are becoming increasingly diverse, polymorphic, and multi-scalar. In addition, the term "planetary urbanization" captures a new aspect of the urbanization process: the emergence of highly heterogeneous and polymorphous extended urban landscapes that are characterized by multi-scalar super-impositions and entanglements of cores and peripheries in urban forms associated with relatively persistent human settlement spaces (Merrifield, 2014). Global urbanization challenges conventional thinking about places not considered urban and long-held notions about urban centres. The term 'concentrated' and 'extended' urbanization describe these two distinct modes of urbanization, both critical (Brenner and Schmid, 2015).

Land is one of the most important natural resources. The way humans have used the land over time is referred to as "land use." Other natural attributes are taken into consideration, but land cover refers to vegetation. Planning, policymaking, and land resource management depend on

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accurate information about land use and cover (Ndukwe, 1997). As a result of this information, cities can be monitored and managed in an efficient and sustainable manner (Ezeomedo, 2006). Geographic information systems (GIS) have also made it possible to incorporate data from multiple sources and dates to generate changes in land use and land cover, including data on things like rate of change and location and magnitude (Adeniyi and Omojola, 1999).

Coppin and Bauer (1996) found that image differencing performed better than other change detection methods on average. Using multispectral satellite data, researchers have shown that land use/cover changes can be detected, identified, and mapped. Image differencing is a popular change detection algorithm (Singh, 1989). Understanding the long-term ecological and developmental impacts of land use change necessitates research into land-use dynamics. Land-use mapping and change detection can now be used as relevant inputs in policymaking for the implementation of appropriate policies (Fasona and Omojola, 2005).

Rapid urbanization in African cities has put enormous strain on these cities' ability to support their residents' infrastructure and service needs. This rapid urbanization crosscurrent has accelerated how man uses space for various human activities. Because of this scenario, land use/land cover change has become a significant problem in many cities; therefore, this paper examines the land use and landcover change in Minna North-Central Nigeria between 1999 and 2019; and spatial characteristics have accelerated the observed spatial changes. The paper sought to analyze the land use/ landcover changes in the City between 1999 and 2019; simulation of land-use changes in Minna for 2029; and assess the roles of city infrastructures such as transportation, education, security, and commercial infrastructure in Minna.

2 RESEARCH METHODOLOGY

This research undertakes a land use land cover analysis of the spatial configuration and appraisal of urban infrastructure occasioned by the continuous rapid urbanization in Minna, North Central Nigeria. The research is based on primary data collected through direct field survey and imageries processing for the purpose of understanding the factors which underpins the spatial changes in the city of Minna and the distribution of urban infrastructure in the City. This section of the research therefore describes the procedure employed in the data collection and processing for the purpose of clearly conceptualizing the research. The section looked at the selection of study period, identification study zones using gradient model, mapping and monitoring of land cover change, and Image classification.

2.1 *Selection of the study period*

From 1999 to 2019, Nigeria's major cities saw a steady influx of people looking for a better life. Massive in-migration from rural areas had resulted in unplanned urbanization in many of these towns and cities. As a result of poverty, rural-to-urban migration has taken place. To commemorate the beginning of Nigeria's democratic rule, 1999 was selected. The annual growth rate of Nigeria's urban population was 4.84 percent, and the country's overall growth rate was 3.20 percent, according to the (UN, 2015).

2.2 *Identification of study zones using gradient model*

An effective way to show the differences between urban and rural areas is to use a gradient model. The current research looked at how cities in North-Central Nigeria have grown both geographically and chronologically. In order to accomplish this, remote sensing and GIS data were combined to perform buffer gradient analysis.

2.3 *Mapping and monitoring of land cover change*

The land cover change information can be achieved from the RS data by applying a range of visual interpretations, land cover classification, and change detection. Generally, the applied methodology is illustrated in Figure 1.

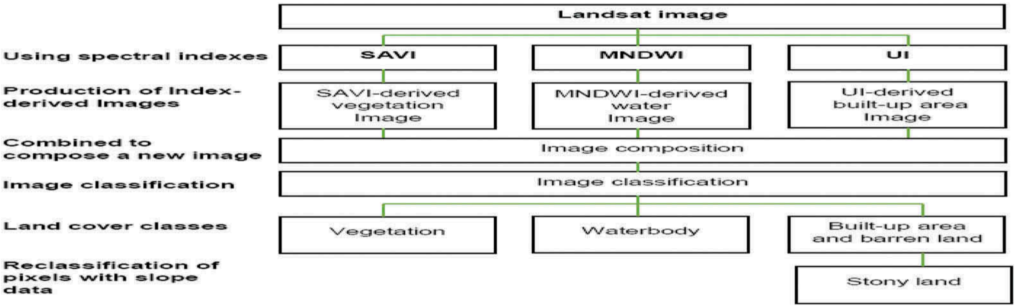

Figure 1. A classification scheme for land cover mapping.

Source: Yuan et al., 2005.

2.4 *Image classification*

Developed in the United States, Anderson's classification system has since become a global standard. Rock faces, rockslides, and cliffs are all included in the new Land class created in this research. Table 1 shows the exposed types, many of which have thick moss and lichen coverings.

Table 1. Land cover classification system.

Land cover categories	Sub-categories
Urban or built-up Land	Complexes of industrial and commercial buildings, as well as residences, businesses, and services, Other urban or built-up land, as well as land that is mixed with the former
Vegetation	pasture and farmland, Orchards, groves, vineyards, nurseries, and ornamental horticultural areas are all included in this category. confinement of the feeding process, Other farmland is available.
	land covered in deciduous trees Forests with a mix of evergreens and deciduous trees
Waterbody	Streams and canals, Lakes, Reservoirs, Bays, and estuaries are included.
Barren Land	Beaches and other sandy areas that aren't beaches
	Rockslides, cliffs, and mountain peaks with rock faces

Source: Author's Analysis based on Anderson I in Yuan et al., 2005.

In the urban or built-up land category, human activities have impacted the landscape in a significant way. As the name suggests, "vegetable" encompasses all land and structures that are primarily used to grow food. The term "water body" refers to any area that is occasionally submerged under water.

3 DATA ANALYSIS AND RESULTS

The process of data analysis and presentation of result is presented in this section of the research. This section looked at the established land use land cover change between 1999 and 2019 and also considered using the Artificial Neural Network by utilizing the add-in in the Q-GIS to project the growth pattern of the city for a Ten-year period to 2029. The outcome of these analysis is presented in this section of the research.

3.1 *Growth analysis of Minna City from 1999 to 2029*

The City of Minna is a nodal town of significant roads linking North-Western Nigeria to the Federal Capital. The railway terminal between South and Northern Nigeria is the amalgamation of two Local Government Areas (Bosso and Chanchaga) and has served as the state capital since 1976. Change in the status of the City has transformed the City into a metropolitan area with a growing population and expanding city limits.

The City was merely about 476.4 Ha of Land in 1976 (Abd 'Razack, 2014) and has grown tremendously as the status changed to state capita. Table 2 shows the spatial growth analysis of the City in 1999, with a total built-up area estimated at 5,501.4 Ha (9.3% of the total space area of the City). Vegetal Cover/Bare ground was estimated at 53,764.6 Ha (90.5%) of the city space in 1999, and 126.0 Ha (0.2%) was made up of water bodies in 1999.

This indicated that the City is growing faster, characteristic of urbanization in Africa.The centralization of government activities, migration of civil servants to new ministries is some of the factors that led to the growth of the City and expansion of the cityscape, which is an 1177% change from its original size in 1976 within the space of 23 years (476.4 Ha in 1976 and 5,501.4 Ha in 1999. Figure 2 shows 1999 to 2029 spatial extent by the different landscapes of the City employing a Global thematic mapper.

Table 2. Growth analysis of Minna City from 1999 to 2029.

Growth Analysis of Minna City in1999		
Landcover	Area (Ha)	% Δ
Built-up	5,501.4	9.3
Vegetal Cover/Bare Ground	53,764.6	90.5
Waterbody	126.0	0.2
Total	59,392.0	100.0
Growth Analysis of Minna City in 2009		
Built-up	8305.3	5,501.4
Vegetal Cover/Bare ground	50624.4	53,764.6
Waterbody	462.3	126.0
Total	59392	59,392.0
Growth Analysis of Minna City in 2019		
Built-up	10,706.7	8,305.3
Vegetal Cover/Bare Ground	48,355.4	50,624.4
Waterbody	329.9	462.3
Total	59,392.0	59,392.0
Growth Projection and Analysis of Minna City in 2029		
Built-up	13251.2	22.3
Vegetal Cover/Bare Ground	45687.2	76.9
Waterbody	453.6	0.7
Total	59392.0	100.0

Source: Author's Computation, 2021

As shown in Table 2 and captured in Figure 2, the total spatial cover of the City was 59,392 Ha (excluding the adjoining villages that are parts of Bosso LGA) and formed the city space identified in 1999. Figure 2 shows that built-up spaces are concentrated within the city centre (around Mobil, Sabon Gari, Railway, and Lagos Street) that form the core of the City's CBD. The image indicated a higher concentration of buildings and physical development within this section of the City. The reason was the nodal nature of the area (This is the nodal point of Tegina, Sule, and Bida traffic, the railway terminus, and the centre of commercial activities). The analysis further revealed that the development of the City is southward as it follows the route that led to the Federal Capital of Nigeria (Abuja) and Northward because of a new development of the airport city and the Airforce base.

3.2 *Growth projection and analysis of Minna City in 2029*

Based on the growth pattern and estimates, it was observed that barring unforeseen circumstances, the growth of the City is on the increase on built-up and shrinking of the bare Land. An annual growth estimate was simulated based on changes, as shown in Table 2. The Table indicated that the annual growth of the built-up area was increasing at the rate of 9.5%, and the shrink in the vegetal cover was 8.2%. Also, the change in land areas covered by water bodies increased annually by 161.8%.

Furthermore, the analysis shows that vegetal cover/bare grounds would be reduced to 45,687.2 Ha reducing by 76.9% of the total spatial extent of the City. In comparison, the waterbody would be 0.7% (covering an area of 453.6 Ha). This spatial growth is projected to be the 2029 human development signature of the cityscape. Based on this estimation, the spatial growth of the City is expected in 2029. The growth is projected to continue uncoordinated through the significant Road apian, city infrastructure provision, and the continuous quest for housing space as dictated by urbanization and population explosion in the City.

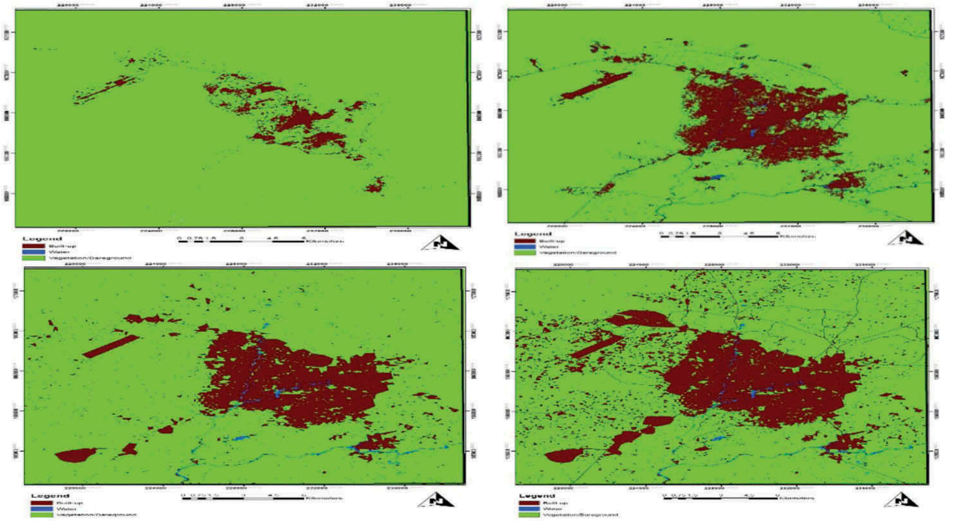

Figure 2. Landcover change in Minna from 1999 to 2019 with simulation of 2029.
Source: GLOVIS, 2021 and Author's Simulation.

3.3 *Land use changes between 1999 and 2029 in Minna*

The underlying factor of the land-use change and land use cover in Minna city ranges from the population explosion to the expansion of government offices. Extending infrastructures such as roads, schools, hospitals, and commercial activities have played a significant role. It will continue to play the role as development is concentrated in the capital city at the expense of other neighbouring towns in the state. Another factor is the spill over effect of the population explosion in the Federal Capital, Abuja.

Table 3 shows a breakdown of spatial and percentage changes in the City of Minna between 2009 and 2019. Between 2009 and 2019, the total built-up areas increased by 4.0%, the vegetal cover/bare ground shrunken by -3.8%, and the waterbody was also observed to shrink by -0.2% over the 10 years. The spatial changes between this period show 2,401.4 Ha of Land developed, 2269.0 Ha of Land lost to development from the vegetal cover and bare grounds, and about 132.4 Ha of waterbody also lost within the period.

3.4 *Infrastructure provision and characteristics in the City of Minna*

The third City considered in this research is Minna, the capital of Niger State. Related research on the infrastructure provision to enhance the liveability of the City was examined.

Table 3. Land use changes between 1999 and 2029 in Minna.

Land-use Change Between 1999 and 2009					
Landcover	1999	2009	Δ	2009%	2009 Value
Built-up	5,501.4	8,305.3	2803.9	4.7	14.0
Vegetal cover/	53,764.6	50624.4	-3140.2	-5.3	85.2
Waterbody	126.0	462.3	336.3	0.6	0.8
Total	59392.0	59392.0		100.0	
Land use Change Between 2009 and 2019					
Built-up	8305.3	10,706.7	2,401.4	14.0	18.0
Vegetal cover/Bare ground	50624.4	48,355.4	-2,269.0	85.2	81.4
Waterbody	462.3	329.9	-132.4	0.8	0.6
Total	59392.0	59392.0	0.0	100.0	100.0

Source: Author's Computation, 2021

The characteristics and functionality of these infrastructures were observed. The infrastructure analysis has the same variables as the other cities earlier assessed. The infrastructure examined are education, healthcare, commercial, recreational, place of worship, and transportation infrastructure. The focus was also on evaluating these infrastructures' locational attributes and distribution patterns in the City of Minna. The analysis employed presentation in tables, photographs, maps, and graphs showing locations and the nearest neighbour analysis.

3.5 *Educational infrastructure in Minna City*

As one of the cities in North-Central Nigeria, Minna was established in the colonial era during the period of establishing railway lines from the South to the North. It became the state capital of Niger State in 1976 by the military decree establishing 12 states in Nigeria.

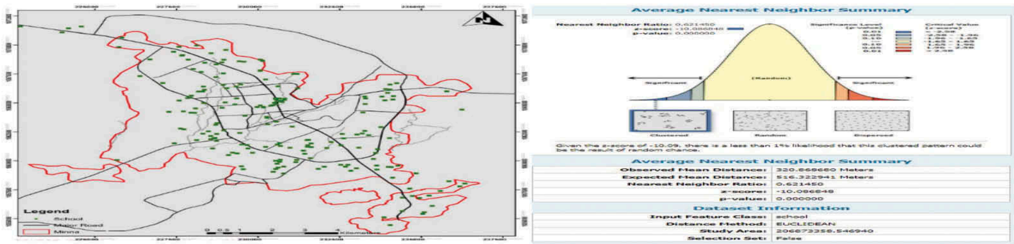

Figure 3. Educational infrastructure and locational attributes in Minna.

Source: Author's Field survey, 2021.

Figure 3 shows the NNA summary of the educational infrastructure in the City of Minna.

Analysis of the educational infrastructure shows a presence of all the educational infrastructure in the City. They are over 50 primary schools, 30 secondary schools (both public and private), and 6 tertiary educational institutions' infrastructure. These are the College of Education, Health Technology, Newgate College of Health, College of Ars and Islamic Studies, and the Federal University of Technology. The Figure shows the spatial location of an array of educational facilities in the City. Furthermore, the City of Minna has the headquarters of the National Examination Council and the Military Training, Doctrine, and Command Centre, an institution for military training in Nigeria. The distribution pattern could result from random chance. The educational infrastructure in Minna is clustered around the various residential neighbourhoods in the City.

3.6 *Mean structural conditions of the educational facilities in the City of Minna*

The analysis of the observation of the educational infrastructure in the City of Minna as one of the factors of urban livelihood indicated a variation in the structural conditions of these educational institutions. The government and private-owned higher institutions and private secondary schools have a good structure, while the public secondary and primary institutions are poorly maintained. Table 4 shows the mean structural conditions of the educational infrastructure in the City. Figure 4 shows a government-owned secondary school under renovation in the City of Minna. Many government schools are now receiving attention for the renovation of these schools.

Table 4. Mean structural conditions of the educational infrastructure in Minna city.

Facility	Mean Structural Condition	Remark
Primary Educational Infrastructure	2.88	Fair
Secondary Educational Infrastructure	3.52	Good
Tertiary Educational Infrastructure	3.81	Good

Source: Author's Analysis, 2021

Figure 4. Ahmadu Bahago and Limawa Secondary School, Minna.
Source: Author's Field Survey, 2021.

3.7 *Healthcare infrastructure locations and distribution in the City of Minna*

Healthcare is a critical component of a healthy city; this was examined in the City of Minna. The result of the analysis of the distribution in the space of the health facilities indicated 17 healthcare facilities in the City, ranging from Primary Healthcare centres to tertiary infrastructure. There are 6 PHCs in the City, 10 secondary healthcare facilities, and one tertiary healthcare facility (IBB Specialist Hospital). Figure 5 shows the spatial distribution of healthcare infrastructure in the City. The locational attributes of healthcare infrastructure in Minna are Dispersed. Figure 6 shows the NNA analysis of the City's locational attributes of health infrastructure.

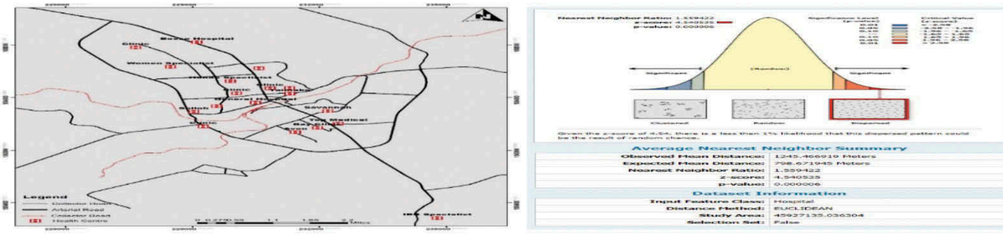

Figure 5. Healthcare infrastructure and locational attributes in Minna.
Source: Author's Analysis, 2021

3.8 *Mean structural conditions of the healthcare facilities in the City of Minna*

The analysis of the observation of the healthcare infrastructure in the City of Minna as one of the factors of urban livelihood indicated a fair structural condition of this healthcare infrastructure. The government and private-owned hospitals and clinics have a fair structure, while the public tertiary healthcare is good. Table 5 shows the mean structural conditions of the healthcare infrastructure in the City.

Table 5. Mean structural conditions of the healthcare infrastructure in Minna city.

Facility	Mean Structural Condition	Remark
Primary Healthcare Infrastructure	3.08	Fair
Secondary Healthcare Infrastructure	3.32	Fair
Tertiary Healthcare Infrastructure	3.57	Good

Source: Author's Analysis, 2021

Figure 6. Example of primary healthcare centre facility in the city of Minna.
Source: Author's Field Survey, 2021

3.9 *Transport infrastructure and services*

Transportation infrastructure analysis of the City of Minna shows an exemplary layout of roads and transport infrastructures (mostly the expressway). Most of the Major Road's designated road furniture, such as Traffic Signals that help promote transport safety, are present and functional. Figure 7 shows the Broadcasting Road in the Tunga area of the City, which has just been reconstructed with critical infrastructure such as drainage lines, paved work paths, and Streetlights along the media divide on the Road. Also, most of the newly reconstructed roads were serviced with road furniture. The City of Minna currently has a central drainage line which helps to de-flood the City after heavy rainfall. This Drainage line has helped to save the City from the impact of the torrential rainfall, which hitherto would have predisposed residents to the adverse impact of flood disaster within the City over time.

Figure 7. Good transport infrastructure and road furniture in Minna.
Source: Authors Field Survey, 2021.

4 DISCUSSION

According to the depicted growth pattern, the City appears to be encroaching on every side, necessitating immediate planning action. The built-up area in the City will increase to about 13,251.2 Ha, covering about 22.3% of the total spatial extent of the City by 2029. The analysis shows that vegetal cover/bare grounds would be reduced to 45,687.2 Ha reducing by 76.9% of the total spatial extent of the City. Extending infrastructures such as roads, schools, hospitals, and commercial activities have played a significant role. Another factor is the spill over effect of the population explosion in the Federal Capital, Abuja. States rather than municipalities should provide public services like schools, hospitals, and public transportation to prevent more pronounced socio-spatial inequality in cities (Burke and Hulse, 2015). Tables, photographs, maps, and graphs were used to show the locations and the nearest neighbour analysis in the analysis.

These areas were given attention: education and health care; recreation; religious institutions; and transportation infrastructure. These infrastructures were observed for their features and functionality. This supports Fincher and Iveson (2008) assertion that redistributive planning has not resulted in "urban landscapes of reduced disadvantage" in cities where funds for services and infrastructure have been channelled more effectively. Accordingly, despite the lofty goals of national policy settings, public policy planning, and implementation often disadvantaged some people and areas. Determining the development trajectory of fast growing urban centres is important because it equips planners, city managers or decision makes with leverage and necessary knowlegde and foresight to influence the future expansions and be ready for the changing structures.

Infrastucture provision can influence the trajectory of urban growth and spatial expansion. This is notice in the study. This lesson is substantiated by Song (2012) whose work stresses that infrastructure has been used as a tool to stimulate the growth of human settlements in many urban areas. The adequacy of infrastructure can contribute to diversifying production, expanding trade, coping with population growth, reducing poverty, or improving environmental conditions and helps determine a country's success.

5 CONCLUSION AND RECOMMENDATIONS

Infrastructure management for maintenance and development is critical for existing limitations to be minimized. Minna's infrastructure facilities are currently being managed by the rules and regulations that have been established. There is room for improvement in the way rules are put into practice at the corporate level. Every link in the infrastructure chain must work together cohesively. Minna's infrastructure and facilities can be better managed if the steps listed below are followed:

- In the first step, a needs analysis is conducted to determine the priority scales; the budget is calculated, and proposals are prepared.
- In order to procure school facilities and infrastructure, the school activity plan and budget are first used to pay for the purchase of school equipment.
- In order to ensure that the school's facilities and infrastructure are in good working order, all school components are responsible for maintaining them.
- Items that aren't feasible are sorted out and new ones are substituted as part of the elimination process (Agustin and Permana, 2020).

Conclusively, the City of Minna depicts an urban environment without proper planning and standards while providing the opportunity for a liveable city. The City is increasing and providing critical infrastructure, but spatial distribution is lopsided. The provision of educational infrastructure is left in the hand of private entrepreneur who provides a better infrastructure to the residents. The effect of this is that the cost of training the young is becoming exorbitant and making literacy beyond the urban poor.

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*Building Smart, Resilient and Sustainable Infrastructure in Developing Countries –
Musonda & Mwanaumo (eds)*

Legal frameworks in construction and demolition waste management

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ABSTRACT: Construction and demolition waste (CWD) is evidently problematic as shown by its indiscriminate disposal on roads, river banks and other open spaces despite the existence of several legal frameworks for managing solid waste. Thus, this study questioned the effectiveness of existing legislations for managing CDW. A predominantly qualitative inquiry, the study collected data using semi-structured questionnaires, observations and documentary review from building contractors, consulting Quantity Surveyors, and regulators, from whom thirty-two participants were conveniently and purposively selected. Data was mainly analysed thematically, and statistically using simple frequencies. Findings indicate that existing legislations were ineffective for managing CDW because they: depend on other legislation for interpretation and enforcement, are outdated to handle challenges of managing solid waste, are numerous and hence, making reference to them becomes cumbersome, and lack meaningful incentives for compliance to encourage monitoring, policing and enforcement. Hence, there is need for a construction industry-specific legislation for waste management.

Keywords: construction solid waste, waste management, disposal, legislation, effectiveness

1 INTRODUCTION

It has been argued that the construction sector is among the biggest contributors to solid waste globally (Sapuay, 2016; Akhund, et al., 2018). Ghaffar, et al (2018) states that the construction sector generates a third of the world's overall waste and contributes at least 40% of the world's carbon dioxide emissions. In Zambia, the construction waste has normally been viewed as any other solid waste (Mulenga, 2018). For this reason there seems to be no statistics on the CDW generation and volumes of CDW disposed of. Nevertheless, the problem CDW management is very real in Zambia and Kitwe in particular. The problem of CDW management in Kitwe has been evidence by CDW disposed of indiscriminately in many townships. Indiscriminate disposal seems to the most preferred management strategy for CDW in Kitwe and other parts of Zambia (Muleya & Kamalondo, 2017), despite the existence of several pieces of legislation such as the Local Government Act (LGA), the Public Health Act (PHA), the Factories Act (FA), and the Environmental Management Act (EMA). A number of scholars have contributed to the discussion on CDW. For instance, Lwanga (2004) discussed the possibility of reusing CDW in pursuit of sustainable development. Muleya and Kamalondo (2017) have examined the waste management practices in the construction industry in Zambian. Based on extensive literature review, Mulenga (2018) addressed the status of CDW waste management in Zambia, and recommended some strategies for sustainable waste minimization and management. This study examined the effectiveness of the existing legal frameworks for managing CDW in Zambia.

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2 LITERATURE REVIEW

2.1 *Understanding construction and demolition waste*

Construction and demolition waste (CDW) sometimes just called construction waste is anything that is generated as a result of construction, renovation, and demolition activities, and then abandoned, regardless of whether it has been processed or stockpiled (Serpel, et al., 1995; Tchobanoglous & Kreith, 2002). CDW comprises a mixture of different material, including inert waste, non-inert non-hazardous waste and hazardous waste that is detrimental to humans and the environment. This waste can be further grouped into physical and non-physical waste. Physical waste constitutes material waste while the non-physical waste constitutes time and cost waste (Nagapan, et al., 2012). The Government of the Republic of Zambia (GRZ) is aware of the environmental, socio-economic, and health consequences related to solid waste and hence, has formulated regulations such as the Environmental Management Act (EMA), the Public Health Act (PHA), and the Factories Act (FA) to assist in the management of waste. However, despite the existence of these pieces of legislation among others, indiscriminate disposal of CDW, a most preferred method of disposal, has persisted (Muleya & Kamalondo, 2017). Consequently, this study questioned the effectiveness of the existing legal frameworks in the management of CDW.

2.2 *Extent of construction waste and demolition disposal*

Currently, there are no statistics on solid waste generation and volumes in Zambia in general and Kitwe in particular. However, in 2012 it was estimated that the country generated about 842 tonnes of solid waste per day, a figure likely to rise to 3,774 tonnes per day by 2025 (Hoornweg & Bhada-Tata, 2012, p. 83). Of all the solid waste generated annually, local authorities collected and dumped in designated dumpsites only 20% while the remainder was dumped on roads, roadsides, and riverbanks (Hoornweg & Bhada-Tata, 2012). Visual evidence from several townships in Kitwe confirmed this claim, and also gives an indication of the extent of the problem of CDW management. Clearly, CDW has been indiscriminately disposed of on tarred and gravel roads alike to fill in potholes (see Figure 1), on roadsides where it is left heaped or spread (see Figure 2) and thrown into streams or on riverbanks (see Figure 3).

Figure 1. Concrete block debris used to fill potholes on Zambezi Road, Riverside, Kitwe.
Source: Authors

2.3 *Effectiveness of legal frameworks in managing construction and demolition waste*

The problem of CDW disposal has been viewed from a number of perspectives including environmental, social, and economic (Coelho & Brito, 2012; Marzouk & Azab, 2014). Therefore, it is imperative to have effective regulation for managing CDW. It has been established

Figure 2. Construction debris spread and heaped along the roadside on Zambezi Road, Riverside, Kitwe.
Source: Authors

Figure 3. Construction debris along the Kitwe stream.
Source: Authors

that the problem of indiscriminate CDW disposal in Kitwe is widespread and quite serious (see section 2.1), and yet there are several legal frameworks that could be used to arrest the situation. This section now examines the provisions within the existing legal frameworks pertaining to handling construction waste.

2.3.1 *Local Government Act of 2019*

In the First Schedule (Clause 10(b), the Local Government Act (LGA) undertakes to "establish and maintain sanitary services for the removal and destruction of, or otherwise dealing with, all kinds of refuse and effluent, and compel the use of those services." Further in Clause 11(j) the LGA provides that the local authority shall "manage refuse removal, refuse dumps and disposal of solid waste" (GRZ, 2019). The Act fails to define the categories of solid waste'. However, since the LGA relies on the Public Health Act (PHA) for addressing issues of public health, the assumption is that 'solid waste' is adequately defined therein to include construction and demolition waste (CDW).

2.3.2 *Public Health Act, Chapter 295 of 1930*

The Public Health Act (PHA), provides for the prevention and suppression of diseases and generally regulates all matters connected with public health in Zambia. The PHA refers to solid waste management in Sections 64-70. In these clauses, the Act prohibits nuisances which include "any accumulation of stones, timber, or other building material if such . . . is likely to harbour rats or other vermin", provides for notification to the nuisance cause, outlines the procedures for enforcement, and finally states the penalty for non-compliance which is a stated "a fine not exceeding one hundred and twenty penalty units for every day during which the contravention continues" (GRZ, 1930). Compared to the LGA, the PHA has endeavoured to define the term 'nuisance' which effectively includes 'refuse' and 'solid waste' alluded to in the LGA (GRZ, 2019).

2.3.3 *Factories Act of 1966*

According to the Factories Act, any site where construction activities take place is defined as a factory that requires to be "kept in a clean state, and free from effluvia arising from any drain, sanitary convenience or nuisance (GRZ, 1966, p. Sect. 82)." This Act is concerned with creating a conducive environment for workers in designated workplaces defined as 'factories' as well as third parties. Hence, in Section 72, the Act provides that "all demolition and operations incidental thereto [building/ construction works] shall be specifically placed under the supervision of a competent person experienced in demolition operations" (GRZ, 1966).

2.3.4 *Environmental Management Act No. 12 of 2011*

In Part IV of the Environmental Management Act (EMA), provisions for waste manage is made in Sections 53 to 63. The EMA, although in general terms refers to how waste (excluding effluent) is to be dealt with regard to collection, reuse, and disposal. However, this study makes specific reference to Section 54 (1-4) which in summary states that in terms of disposal, no one is supposed to dispose of no person "in a manner that results in an adverse effect, or creates a significant risk of an adverse effect occurring." Therefore, if one was found to contravene the provision, such a one "commits an offence and is liable, upon conviction, to a fine not exceeding fifty thousand penalty units or to imprisonment for a period not exceeding six months, or to both" (GRZ, 2011).

All of the above pieces of legislation are cognisant of the problem of management of solid waste. Although the LGA was recently amended (2019) it is oblivious to the problem of solid waste because it fails to even define 'refuse' and 'solid waste'. Its reliance on the PHA does pan out because the term 'nuisance' assumed to mean 'refuse' and 'solid waste' in LGA, is defined to include many forms unwanted materials including construction and demolition waste (CDW). The FA which has ably defined any site where construction or building activities take place as a 'factory' also fails to provide for disposal of waste therefrom. An assumption is made here that perhaps the FA like the LGA, depends on the PHA interpretation and enforcement of its provisions. Lastly, EMA mentions 'waste' but it also fails to categories the types of waste referred to.

There is a wealth of evidence of the existence of legislation to assist with managing solid waste management. However, from document analysis the study made the following observations:

a) Pieces of legislation rely heavily on others for interpretation and enforcement of provisions.
b) Some pieces of legislation such as the Factories Act (FA) and the Public Health (PHA), although they have had several amendments, are too old that they cannot cope with the challenges of managing solid waste in general and CDW in particular.
c) There are rather too many pieces of legislation to refer to and that becomes a very cumbersome process for people.
d) Apart from EMA that provides for fines or imprisonment or both for offenders, the PHA only provides for a fine after a protracted legal procedure while the LGA and FA offer no tangible penalties to offenders.

3 METHODOLOGY

3.1 *Research approach, design and data collection and analysis methods*

This research, being a qualitative inquiry sought an in-depth examination of the effective-ness of existing legal frameworks to manage construction and demolition waste (CDW). Hence, it adopted a case study design to investigate the phenomenon in its natural environment (Yin, 2014; 2018). Data for the study was collected mainly through semi-structured questionnaires which contained both open-ended and closed questions. Additionally, the study used observation (Cooper & Schindler, 2014; Saunders, et al., 2019) to understand the situation based on what was visible to the eye with regard to the extent of the problem of construction and demolition waste (CDW). Moreover, the study conducted documentary review (Creswell & Poth, 2018) of several pieces of legislation relating to waste management in Zambia such as the LGA, PHA, FA, and EMA to examine them for effectiveness in managing CDW. The data gathered from semi-structured questionnaires, observations, and document reviews were analysed thematically following a rigorous process of coding of data, identifying and categorizing of themes (Braun & Clarke, 2013). Additionally Microsoft excel was used for graphical presentation of numerical data.

3.2 *Research targets and sampling*

Five main research target groups were identified that included building contractors, Quantity Surveying (QS) consultancy firms, Kitwe City Council (KCC), National Council for Construction (NCC), and Zambia Environmental Management Authority (ZEMA) (see Table 1). As a predominantly qualitative inquiry, this research employed non-probability sampling, which refers to sampling techniques in which an element's likelihood of being selected for inclusion in a sample is unknown (Dattalo, 2008; Blackstone, 2012). Therefore, the study used convenience (availability) sampling to select participants from building contractors and QS consulting firms while purposive (judgemental) sampling was used to select participants from KCC, ZEMA, and NCC (see Table 1). As such, a total of thirty-two (32) participants were involved in the study and to whom semi-structured questionnaires were distributed.

Table 1. Target groups, sampling methods, respondents, and methods of collecting data.

Target Group	Sampling Method	Expected # of Respondents	No. of Respondents	Method of Collecting Data
Building Contractors (Grades 1-5)	Convenience	33	21	Semi-structured questionnaires
QS Consulting Firms	Convenience	15	8	Semi-structured questionnaires
Regulators ZEMA (Inspectorate) KCC (Inspectorate) NCC (Inspectorate)	Purposive	3	3	Semi-structured questionnaires
Total		51	32	

4 RESULTS AND DISCUSSIONS

4.1 *Understanding the nature of construction and demolition waste*

In order to understand the nature of CDW in Kitwe, the research sought to establish the preferred mode of managing CDW in Kitwe. Results show that the majority of the respondents identified disposal as the most common method of managing CDW, while only few respondents stated that CDW reused (see Figure 4). This result is consistent with findings from literature review where Muleya & Kamalondo (2017) noted that disposal was the most preferred method of managing CDW. Additionally, the result is consistent with observational data which showed CDW disposed of on roads, roadsides and riverbanks (see Figures 1-3).

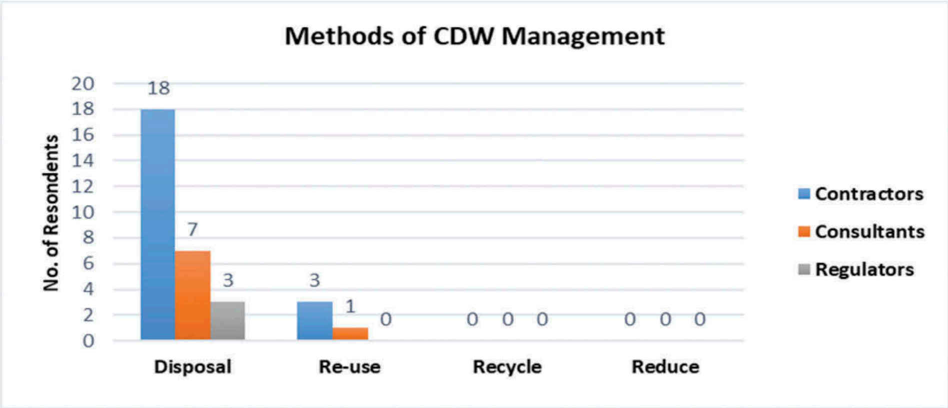

Figure 4. Method of construction and demolition waste management.

Further evidence from observational data from different townships showed that disposal of CDW was done in various different ways including dumping behind wall fences (see Figure 5), using it as filling on road potholes (see Figure 6), and just dumping in 'convenient' places (see Figure 7). The fact that CDW is being used to fill potholes on roles seems to explain why some respondents believed that CDW was being re-used and hence, totally missing the meaning of reuse.

Figure 5. Broken PVC tiles and concrete debris dumped behind wall fences in Riverside.
Source: Authors

4.2 *Extent of the construction and demolition waste problem*

Having gained an insight into how CDW was generally managed, the research sought to establish the extent of the problem of CDW disposal in the city. Evidence from observational data from five townships in Kitwe showed that the problem of CDW disposal was widespread in all the major townships around the central business district (CBD) (see Figures 5-7). This finding is consistent with findings from literature where Hoornweg and Bhada-Tata (2012) noted that whereas local authorities collected and dumped in designated areas only 20% of the total solid waste, the rest was dumped on roads, roadsides, and riverbanks.

Figure 6. Construction Debris used as filling on roads in Buchi and Nkana West, respectively.
Source: Authors

Figure 7. Construction Debris dumped in Ndeke and Kwacha East, respectively.
Source: Authors

4.3 *Effectiveness of the legal frameworks in managing on construction waste*

The main aim of this research was to investigate the effectiveness of the existing legal frameworks relating to solid waste management to manage CDW. In establishing effectiveness of the existing legal frameworks for managing CDW, the study considered the easy of understanding and interpretation, clarity, and enforcement of legal provisions in the pieces of legislation reviewed. A review of the LGA, PHA, FA, and EMA revealed that all of these pieces of legislation are aware of the problem of solid waste. However, they generally lacked in the three criteria mentioned above. Although recently amended (2019), the LGA is rather 'silent' on the problem of solid waste because it fails to even define 'refuse' and 'solid waste'. Its reliance on the PHA somewhat pans out because the term 'nuisance' assumed to mean 'refuse' and 'solid waste' in LGA, is defined to include many forms of unwanted materials including CDW. The FA which has ably defined any site where construction or building activities take place as a 'factory' also fails to provide for disposal of waste therefrom. An assumption is made here that perhaps the FA like the LGA, depends on the PHA for interpretation and enforcement of its provisions. Lastly, the EMA mentions 'waste' but also fails to categorize the types of waste referred to. There is a wealth of evidence of the existence of legislation to assist with managing solid waste. However, the following observations render these legal frameworks ineffective for use in managing CDW:

a) Pieces of legislation rely heavily on others for interpretation and enforcement of provisions.
b) Despite having had some amendments, some of the legal frameworks such as the FA and the PHA were too old and redundant to cope with the challenges of managing solid waste.
c) There are too many pieces of legislation to refer to and that becomes very cumbersome.
d) There are no meaningful incentives for compliance. Apart from EMA that provides for fines or imprisonment or both for offenders, the PHA only provides for a fine after a protracted legal procedure while the LGA and FA offer no tangible penalties to offenders.

In addition to documentary review data, the effectiveness of the existing legal frameworks is evidenced by illegal disposal of CDW as the most preferred method (see Figure 4). This study recommends that comprehensive legislation be promulgated to adequately address the management of waste in the construction industry.

4.4 *Need for specific law for construction waste*

Considering the fact that existing legal frameworks were seemingly infective for managing CDW, the research sought to find out if there was a need for an industry-specific waste management legal framework. The majority of the respondents indicated in the affirmative the need for a construction industry-specific solid waste management legislation (see Figure 8). This finding appears to respond to the evidence from documentary reviews (see section 2.3) which has shown the challenges with existing legal frameworks that make them ineffective for managing CDW.

The respondents who did not want an industry-specific CDW legislation (see Figure 8) felt that the existing legal frameworks were sufficient and just needed some amendments. However, their claim seems contrary to evidence collected through documentary reviews which indicates that the legal frameworks are ineffective (see section 2.3). Although some legal frameworks have endeavoured to define waste, particularly solid waste, they have still failed to categorise this waste and how it should be managed. The other legal frameworks have entirely failed to define waste or some of the synonyms used such as ‘refuse’. One of the regulators claimed that a newly enacted legislation, the Solid Waste Regulation and Management Act (SWRMA) No. 20 of 2018 also covered solid management. A scrutiny of the SWRMA revealed its main objective was to usher in solid waste service providers to allow local councils to outsource the service for solid waste management. Although, Section 79 labours to outline the penalties for illegal solid waste dumping, the new Act still falls short on the implementation of the said penalties for lack of policing mechanisms.

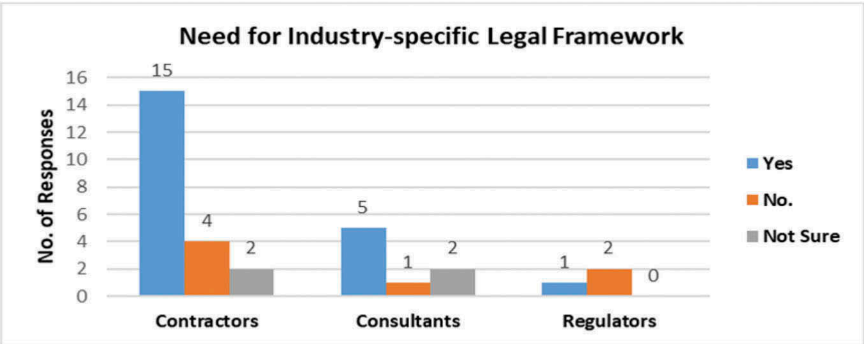

Figure 8. Need for industry-specific legal framework.

5 CONCLUSION AND RECOMMENDATIONS

This research sought to investigate the effectiveness of existing legal frameworks for managing CDW in Kitwe. The research has established that established that the existing legal frameworks were ineffective in managing CDW for the following reasons:

a) Pieces of legislation rely heavily on others for interpretation and enforcement of provisions.
b) Despite having had some amendments, some of the legal frameworks were too old and redundant to cope with the challenges of managing solid waste.
c) There are too many pieces of legislation to refer to and that becomes very cumbersome.
d) There are no meaningful incentives for compliance. Apart from EMA that provides for fines or imprisonment or both for offenders, the PHA only provides for a fine after a protracted legal procedure while the LGA and FA offer no tangible penalties to offenders.

Therefore, it is logical to state that because of the ineffectiveness of the existing legal frameworks, the problem of CDW disposal is widespread in Kitwe. The research has shown that the practice of having legal provisions for managing solid waste management scattered in various legal frameworks while their interpretation depends on other related pieces of legislation, creates a gap in the management of CDW. This results in the failure to monitor, police, and enforce penalties related to unauthorised CDW disposal. This research recommends formulating a construction industry-specific legislation for waste management which would among other things clearly define and categorize construction waste, outline the penalties for non-compliance, and set procedures for enforcement of the provisions therein.

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